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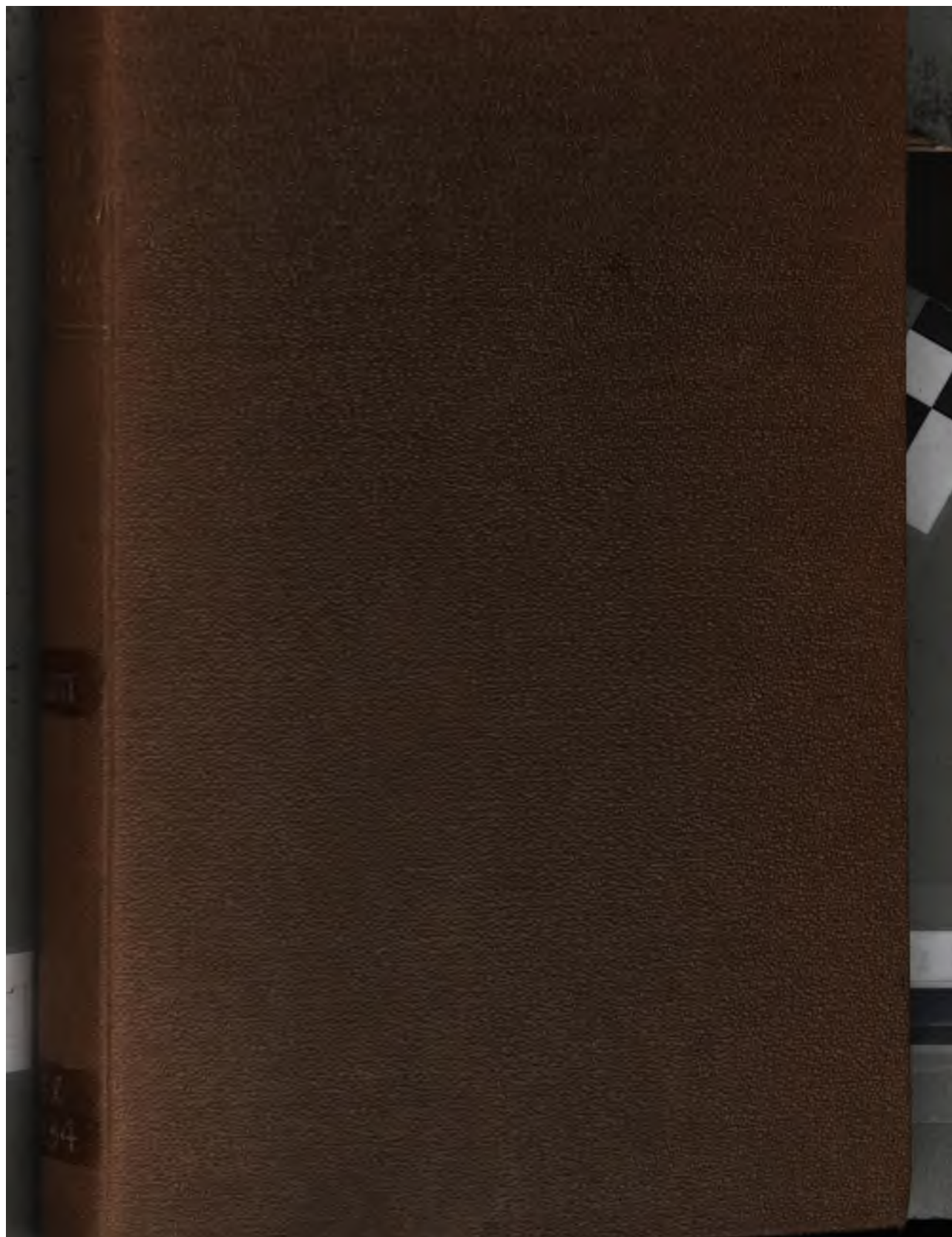
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Philosophical Society  
of Glasgow.



PROCEEDINGS  
OF THE  
PHILOSOPHICAL SOCIETY  
OF GLASGOW.

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PROCEEDINGS  
OF THE  
PHILOSOPHICAL SOCIETY OF GLASGOW.

EIGHTY-NINTH SESSION.

I. — *Human Muscle as a Transformer of Energy.* By JOHN  
G. M'KENDRICK, M.D., LL.D., F.R.S., President.

PRESIDENTIAL ADDRESS.

[Read before the Society, 4th November, 1891.]

THE principle of the Conservation of Energy has been applied with considerable success by Mayer, Joule, Hirn, von Helmholtz, Berthelot, and Chauveau to physiological phenomena, and more especially to those manifested by living muscle. Muscles liberate energy as heat and motion. Every one knows that it is by the contractions of the muscles that the levers formed by the bones and ligaments of the body are moved, and every one knows also that the body is warm, and maintains a fairly constant temperature. It is also a familiar experience that when we bring many muscles into play, as in climbing a hill, or ascending a ladder, or carrying a heavy weight, we feel warmer, and at the same time the skin becomes bedewed with perspiration. If the muscles are thus expending energy, it is evident that this loss must be compensated. Energy must be supplied to the muscles, and it scarcely requires to be said that the source of the energy must be traced to food materials and oxygen, both of which are brought to the muscles

by the blood. The muscles, then, may be regarded as machines or engines or motors for the transformation of energy, and they may be compared to other well-known thermic, electric, or hydraulic motors.

This comparison has always had a fascination for physicists and physiologists, and the attempts made by many eminent men to work out the problem have been singularly fruitful to science, not only as regards the physiology of muscle, but also as regards animal heat and the applications of the laws of thermo-dynamics to living beings. As the subject has recently engaged my attention, I have thought that it might not be uninteresting to the members of the Philosophical Society to bring before them the result of my reading and reflections.

The old philosophers attributed the production of heat to the action of a vital principle. Vital heat was continually developed, and the body, they alleged, would be consumed by its own heat if it were not cooled by the process of respiration. In those days, the great thoughts had not arisen that as nothing can come from nothing, light and heat cannot spring out of nothing but only represent forms of energy. The first step towards a sound knowledge of the origin of animal heat was taken late in last century by those immortal workers who laid the foundations of modern chemistry. Priestley, Cavendish, and Black recognised that the animal body was the seat of chemical changes; Crawford, in 1779, made the remarkable statement that "Animal heat seems to depend upon a process similar to a chemical elective attraction;" and in the following year Lavoisier published his famous researches on respiration. There can be no doubt that the great Frenchman was the first to shed light on the problem of animal heat. Reasoning that as flame, hitherto considered as an element, was caused by the chemical combination of certain bodies with oxygen, he conjectured that respiration was for the purpose of supplying the body with oxygen, and that thus an internal combustion was produced which was the chief source of animal heat. Experiments proved that the conjecture was sound, and thus the foundation-stone of this department of science was securely laid.

Since the time of Lavoisier, by calorimetric methods, the heat produced by the combustion of many elementary, and of not a few complex substances and food-stuffs has been approximately determined; and, by similar methods, attempts have been made to estimate the heat developed by the body of a man, both while at

rest and while performing mechanical work. Finally, the heat developed by isolated muscles, while at rest and while at work, has also been measured. The great progress that has been made in thermo-dynamics has given precision to these researches, not merely as regards the development of refined experimental methods, but more especially by defining the units of heat and of work, the calorie and the kilogrammetre.\*

Taking the body as a whole, attempts have been made to construct a balance sheet, showing, on the one side, the income of energy, and, on the other, the expenditure, for a period of twenty-four hours. The income consists, in the first place, of the potential energy in the food-stuffs, set free by the chemical operations occurring in the body; and it has been assumed that these operations are essentially oxidations, brought about by the interplay of these food-stuffs and the oxygen introduced by respiration.† To this must be added energy as heat coming from other sources than combustion, say, from warm fires; and from the sum must be deducted the energy still existing in excrementitious matters that have not been completely oxidised. On the other side, we place the energy liberated during, say, nine hours, as mechanical energy, and the energy represented by the heat set free during the whole period. The heat is expended in warming the food and drink, in warming the air respired, in converting into vapour the water exhaled from the respiratory surfaces, while the remainder is lost by radiation, conduction, and the evaporation of sweat. The energy represented by the so-called internal work of the body—namely, the mechanical energy of the heart in forcing the blood through the vessels, the movements of the respiratory muscles, and the frictiona

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\* The unit of heat or *calorie* is the amount of heat required to raise the temperature of 1 kilogramme of water 1° centigrade; or, strictly, from 15° to 16° centigrade. A *small calorie* is the  $\frac{1}{1000}$ th part of a *large calorie*, or it is the heat required to raise 1 gramme of water 1° centigrade. The heat unit may be transmuted into the work unit by multiplying by 425, and the reverse is accomplished by dividing by the same number, for the weight of 1 kilogramme falling 1 metre in height in one second will produce the same amount of heat as will raise 1 kilogramme of water from 15° to 16° centigrade.

† It is convenient to regard some of the chemical phenomena in the living body as oxidations, but it is probable that they are more of the nature of fermentations, or changes brought about in fermentable matter by the action of the living substance, or protoplasm.

movements of one part of the body upon the other—need not appear in the account (unless it is subtracted from the total heat), as these movements are all ultimately resolved into heat. Such attempts to strike a balance are not very successful; they lack scientific accuracy, as it is almost impossible experimentally to obtain all the data from one individual, and certain items in the account have to be supplied from other sources. Still, the balance sheet shows amounts so nearly alike on the two sides as to prove that the body may be considered from this point of view as a machine, the income and output of which, both as regards matter and energy, are controlled by the same laws as regulate the motors made by man.

Suppose we take a man of average weight, say 85 kilogrammes, (187 lbs.), and in excellent health, and place him in a properly constructed calorimetric chamber in which he will be at liberty to stand, sit, or lie down at pleasure, and without uneasiness or restraint. Let us suppose, also, that we have an arrangement by which he can perform mechanical work for nine hours of the twenty-four in which he resides in the chamber, and that the amount of this mechanical work can be measured and registered in units of heat. Suppose, further, that he receives a diet suitable for a man doing this amount of work, and that the calories obtained by the combustion of this food have also been calculated. Finally, let us suppose that the excreta passed during the twenty-four hours are collected, and their calorimetric value also ascertained. No doubt it would be difficult to carry on this experiment for a period of twenty-four hours, but such experiments have been made by Hirn, a well-known authority on this subject, for a period of one hour in each case, and it would be a matter only involving trouble and special arrangements to maintain the conditions for twenty-four hours.

We will allow the subject of experiment a diet equal to that supplied to the Royal Engineers of the British army when they are engaged in active service. This is selected as a diet suitable for a healthy man doing vigorous work for nine hours per day. The result would probably come out in the following balance sheet, in which the figures have been calculated from data given by Hirn in his well-known calorimetric experiments on man\* :—

---

\* For a summary of Hirn's latest views and figures, see *La Revue Scientifique*, XIII., 1887, 3<sup>me</sup> série, pp. 673, 714, and 779.

INCOME.				
1. Food—	Proximate Compounds.	Amount in Grammes. a.	Calories produced by Combustion of 1 Gramme. b.	Amount of Heat in Calories. a X b.
				Total Calories.
	Proteids, - -	144	6·250	900
	Fats, - - -	82	9·842	807
	Carbo-hydrates, -	630	4·479	2,821
	Salts,* - - -	30	0	0
				<hr/> 4,528
2. Heat, from external sources, - - - -				500
				<hr/> 5,028
Less heat obtained by combustion of matters in the urine and fæces that have not been oxidised, say, - - -				500
				<hr/> Total income of Energy, - - - - 4,528

EXPENDITURE.				
1. Work, for nine hours, at 84·7 calories per hour, - - -				762
				Calories.
2. Heat, during nine working hours, at 260 calories per hour, - - -				2,340
3. Heat, during seven hours rest, at 140 calories per hour, - - -				980
4. Heat, during eight hours sleep, at 40 calories per hour, - - -				320
				<hr/> 3,640
Total output of Energy, - - -				4,402
Balance in favor of Income, - - -				<hr/> 126

The total heat produced is, in calories, ... 3,640  
This amount, according to the estimate of Helmholtz, is disposed  
of as follows:—

1. To heat the food and drink to a temperature of 12° centigrade, 2·6 per cent. of the total, ...	94·64
2. To heat the air respired, 2·6 per cent., ...	94·64
3. Heat rendered latent by evaporation of water exhaled from respiratory organs, 15 per cent., ...	546·00
4. Heat lost by radiation, and conduction carried off by fæces and urine and by evaporation of sweat, 79·8 per cent., ...	2904·72
	<hr/> 3,640

\* These supply no energy to the body, and their value as food-stuffs depends on the physical modifications which they make in the media in which the chemical phenomena of life occur.

The internal work of the body, including under this term the work of the heart, the work of the respiratory muscles, and the heat produced by frictional movements, amounts to a little over 240 calories; but, as already remarked, the whole of this energy is ultimately resolved into heat, and need not therefore appear in the balance sheet. According to this computation, of the total energy supplied to the body by the food, about 17·4 per cent. is returned as mechanical work.\* It has frequently been pointed out that the return made by the animal machine compares favourably with the results obtained from our common motors, steam and gas engines; but this view of the question will be discussed after we have considered more minutely the behaviour of a muscle.

In calculating the calories of combustion of food-stuffs, I have taken the figures from those published recently by Danilewski and Rechenberg. These figures may now be substituted in discussions on this question for the somewhat antiquated results published by Frankland †:—

<i>DANILEWSKI.‡</i>				Calories.
1 gramme	Fibrin,	...	...	5·830
„	Casein,	...	...	5·950
„	Vegetable albumen,	...	...	6·250
„	Peptone,	...	...	4·900
„	Fat,	...	...	9·842
<i>RECHENBERG.§</i>				Calories.
1 gramme	Starch,	...	...	4·479
„	Dextrose,	...	...	3·939
„	Mactose,	...	...	4·163

There is, however, another route by which we may approach the subject. If the energy of the body is derived from combustion, we should be able to calculate the amount received from the amount of oxygen used, say, in twenty-four hours; and if we find the result corresponds with that obtained by the other method, we shall feel more confidence in our balance sheet. Hirn found that during

\* 1 kilogrammetre = 7·23308 foot-pounds, and 1 foot-pound = ·138254 kilogrammetre. To convert the above computations into foot-pounds, multiply the number of calories by 425, and the result by 7·233.

† Frankland. *Philosophical Mag.*, xxxii.

‡ Danilewski. *Pflüger's Archiv.*, t. xxxvi., p. 230, 1885.

§ Rechenberg. "Ueber die Verbrennungswärme organischer Substanzen." Leipzig. 1880.

hard work, on an average, 123 grammes of oxygen were consumed per hour, while the quantity was reduced to 25·4 grammes per hour during the period of rest. Suppose, again, that the man worked hard for nine hours—the probable consumption of oxygen would then be for the twenty-four hours as follows:—

				Grammes.
9 hours work :	123 grammes × 9,	...	...	1,107
15 hours rest :	25·4 ,, × 15,	...	...	381
				<hr/>
Total,		...	...	1,488

This is nearly double the quantity given in physiological text-books as the amount of oxygen used in twenty-four hours, but the difference is due to the large increase in the consumption of oxygen during a period of nine hours of hard labour. If we knew the amount of heat evolved by the combustion of one gramme of oxygen when used for the destruction of the different dietetic proximate compounds, we would be able to estimate the amount of heat produced by the combustion of 1,488 grammes. This information is found in the following table, which gives the number of calories set free by unit weight of oxygen consumed, of carbonic acid exhaled, of nitrogen or urea excreted, connected with or arising from the destruction of albumen, fat, starch, and dextrose :—\*

HEAT OF COMBUSTION IN CALORIES OF ONE GRAMME.

	O absorbed.	CO <sub>2</sub> exhaled.	N excreted.	Urea excreted.
Animal albumen,	3·380	2·930	31·800	14·860
Fat,	3·370	3·460	—	—
Starch,	3·797	2·750	—	—
Dextrose,	3·695	2·687	—	—

The table reads thus :—For each gramme of oxygen consumed in destroying animal albumen 3·38 calories of heat are produced ; or, for each gramme of carbonic acid exhaled in consequence of, or associated with, the destruction of animal albumen, 2·930 calories are produced ; or, for each gramme of nitrogen excreted in the decomposition of animal albumen, 31·8 calories are set free ; or, for each gramme of urea excreted in the decomposition of animal albumen, 14·860 calories of heat are set free. Again, for each

\* Léon Fredericq. "Chaleur et travail musculaire." *La Revue Scientifique*, XIII., 1887, 3<sup>me</sup> série, p. 466.

gramme of oxygen used in destroying fat, 3·370 calories are produced; in destroying starch, 3·797 calories; and in destroying dextrose, 3·695 calories. Lastly, for each gramme of carbonic acid exhaled, associated with the destruction of fat, 3·460 calories are set free; of starch, 2·750 calories; and of dextrose, 2·687 calories. It will be observed that each gramme of oxygen consumed produces almost the same amount of heat, whatever may be the nature of the substance oxidised in the body. Assuming a mixed diet, let us take the mean of these figures for oxygen, namely, 3·56, and multiply by 1,488. This gives 5,297·28 calories, a result approximately near that obtained by the other method of computation.

From the physical point of view, therefore, it is clear, theoretically, that a balance can be struck between the income and the output of energy in a living being like man. The chemical reactions occurring in the body are the source of the energy set free, either as heat or external mechanical work, or both. The physiologist, however, is not satisfied with the striking of this balance sheet. His science leads him to the study of the intermediary changes that occur between the chemical phenomena and the final production of thermal energy and of mechanical energy; and the tissue in which these changes may be most conveniently studied is muscle. Muscles work and produce heat. What is the relation existing between these two functions? Are they independent of each other; or is the heat set free in a muscle by chemical changes partly liberated as heat and partly converted into mechanical energy? These are questions that have in recent years been very fully discussed both by physicists and by physiologists, and on the answer to be given depends our conception of a muscle considered as a motor or heat machine.

Does the muscle resemble a heat machine which transforms heat into work? This question was first put and answered in the affirmative by J. Mayer, but it has been answered in the negative by the majority of physicists and physiologists, because they do not find in muscle one of the essential conditions of all such machines—namely, a marked difference of temperature between one part and another.

Let us consider shortly the arguments of those who uphold the hypothesis of the thermic origin of the mechanical energy manifested by a muscle.

The view in question is clearly put by Gavarret in an article on "Animal Heat."\* "Muscle is a living motor, similar to a steam engine, utilising heat for the production of work." An internal combustion, with production of heat, opens the series of acts that end in muscular contraction. A "certain definite portion of the heat thus produced" disappears "as a thermic agent, is used up by the *internal work* which accompanies the contraction, and is *transformed into contractility*." If a muscle in contracting does not perform external work "all the heat consumed by the *internal work* accompanying the contraction, or *transformed into contractility*, reappears in the state of *sensible heat* when the muscle is relaxed."

In a perfect steam engine, for example, which performs mechanical work by the to-and-fro movement of the piston, the essential condition is a great fall of temperature between the boiler and the condenser, favouring the return of the piston after it has been raised by the passage of steam into the cylinder. Herzen† points out, however, that a muscle cannot be regarded as a perfect machine, the piston of which moves in each direction. It is rather a machine in which the piston moves only in one direction; another cylinder and piston are required to produce a movement in the opposite direction. He calls an active muscular mechanism a single-acting machine. Thus the biceps flexes the forearm on the arm, but it cannot extend the forearm that has been flexed. To accomplish extension, the triceps muscle on the back of the arm must be brought into play. Any continuous movement, such as walking, flying, or swimming, requires two independent machines, each of which does its work without any arrangement comparable to the mechanism of a boiler and condenser. The arrangement for the movement of a limb is as if the engineer obtained a rapid to-and-fro movement of the piston, by employing two boilers, and by allowing the steam of the one to press the piston behind, and the next instant the steam of the other to press the piston in front. For these reasons, Herzen thinks that, as regards muscle, all arguments founded on the necessity of a considerable difference of temperature between two parts of the organ fall to the ground. He

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\* "Chaleur Animale." *Dictionnaire Encyclopédique des Sciences Médicales*. 1<sup>re</sup> série, t. xvi., p. 79.

† "L'activité musculaire et l'équivalence des forces." *La Revue Scientifique*, XIII., 1887, 3<sup>me</sup> série, p. 257.

holds that the transformation of heat into mechanical energy really occurs, both when the muscle does work in lifting a weight, and even when it contracts without lifting a weight. When a muscle, having no resistance to overcome, contracts, it displaces to some extent its own mass, and it overcomes the internal resistance of its own substance and of its coverings. If we suppose that molecular movements occur in the muscle substance when it contracts, these must be regarded as internal work, consuming a certain amount of heat. In discussing this question one must not forget, however, the important part played by the elasticity of muscle. Like a band of india-rubber, a muscle becomes warmer when it is stretched, and it cools when it retracts. The contraction of muscle may be regarded as a sudden and strong retractile action. If so, a muscle ought then to become *colder* when it contracts. But this is apparently contrary to experience. Thermometric observations on a contracting muscle indicate a rise and not a fall of temperature. On this point there is great conflict of opinion. Some hold with Herzen that the contraction actually lowers temperature, but that the fall is hidden, and more than counter-balanced by the heat set free by the chemical changes occurring in the muscle. It is quite true that a thermometric observation gives us the temperature only at a moment of time, and that the increase may be the algebraic sum of a series of operations in the muscle having a heating effect partially neutralised by a simultaneous operation (the contraction) having a cooling effect.

According to this view, two operations occur in a muscle—a physico-vital phenomenon of contracting, which absorbs heat, and a chemical phenomenon, which produces heat. Then, if the first occurred without the second, the muscle should become colder; and if the second occurred without the first, the muscle should become hotter than it would be if a contraction had also taken place, by exactly the amount of the heat that would have been absorbed during the contraction. Here, however, experiment has given doubtful results. It is manifestly almost impossible to separate the two classes of phenomena, even supposing them to exist. Solger, Mayerstein, and Thiry have noted a slight cooling effect at the beginning of contraction, but Valentin and Heidenhain have not confirmed this observation. Herzen, with great ingenuity, suggests that in a fresh muscle the substances which are the seat of chemical changes exist in large amount, and that when such a muscle contracts the heat produced by these

changes is so great relatively to the heat absorbed by contraction as to make it impossible to observe any cooling, and he thinks that the cooling effect would probably be discovered in fatigued muscles in which the heat-producing substances have already been used up.

Certain experiments made by Heidenhain in his well-known research appear to favour Herzen's hypothesis. He found that as a muscle became fatigued the quantity of heat set free diminished much more rapidly than the energy of the contraction, as measured by the amount of work done. Thus, in one series of experiments on a muscle, the first observation, made when the muscle was fresh, indicated 190·5 gramme-millimetres of work, and 6·5 degrees on the scale of the thermal galvanometer, while the last experiment registered 117 gramme-millimetres, and only 1 degree on the galvanometer scale. In another series, the first experiment recorded, of work 517, and of heat 7·5, and the last, of work 324, and of heat 2·5; and in a third series, the first readings were 1,080 of work and 12 of heat; and the last, 380 of work and 2·5 of heat. Thus the production of heat fell off at a much more rapid rate than the production of work, so that, in the same time, the heat diminished to about one-fifth, while the work was reduced by only about one-half or one-third. Herzen is of opinion that if Heidenhain had prolonged these experiments he might have reached a point when the heat would have disappeared, and a real cooling effect might then have been observed.

Another series of experiments by Heidenhain has been brought into court in support of the contention that contraction produces a cooling effect. Heidenhain caused a muscle to lift to a given height the same weight three times in succession. Suppose that the positive work of raising the weight was exactly compensated by the negative work of lowering it, so that negative work restored to the muscle the heat absorbed by it while doing positive work. If we subtract from the heat observed by Heidenhain the thermic equivalent thus restored, at the close of the series the figures of the experiments would become negative; that is to say, if the positive work had not been entirely compensated, the galvanometer would have shown a slight cooling effect at the time of contraction. In addition, as a muscle becomes warmer when stretched, it is evident that some of the heat observed might be due to the extension of the

muscle when the weight pulled it out after contraction. This heat should also be subtracted from the heat actually observed. Danilewski has succeeded in making an experiment by which this somewhat difficult point is made clear. He caused a muscle to lift a weight a certain height, but the weight in falling was detached from the muscle and allowed to descend by an india-rubber thread. The heat effect was observed by a thermal pile and a galvanometer; and he found that in these circumstances the heat evolved became much less in amount, and in some experiments he obtained a distinct cooling of the muscle. That is to say, according to theory, heat was used up in the contraction of the muscle, and as it was not restored by the falling weight, and, as the muscle was not made warmer by extension, it became colder in proportion to the mechanical work accomplished. Blix has also investigated this question, using refined appliances, with the general result that when the muscle contracts without performing mechanical work; that is to say, when it has no weight to lift, no resistance to overcome, it becomes warmer; but when it contracts, and does positive work by lifting a weight or overcoming a resistance, the muscle becomes colder.

Danilewski has also made the important observation that the muscles which were the subjects of his experiments had a high thermic equivalent relative to the positive external work actually done. They used more heat than could be accounted for by the work done. The excess of heat thus absorbed is probably used up in the internal molecular work, associated, in some way not yet unveiled, with contraction of the molecular substance.

Certain of the statements made in the foregoing argument may be admitted, while others are open to objection. According to Carnot's theorem, a thermic motor can only act continuously when a difference of temperature has been produced at one portion of it so that a certain amount of heat flows from the point where the temperature is high, to another point where the temperature is low, and a portion of this heat may be employed in working the machine. No motor suitable for continuous work can operate without a difference at two points in the intensities of the dynamic element in the motor. Thus, in electro-dynamic machines, a current can only be produced when there is a difference of electric potential at two points of the conductor. A hydraulic motor also requires a difference of water level. The same must hold true of an organic

motor like a muscle, although we may not be able to define the two points at which there is a difference in the intensity of the dynamic change. The nervous influence causes the muscles to contract, and either at the point where the nervous influence originates, or where it acts on the muscle, there must be a difference in the intensity of the dynamic flow, or current, or stimulus, from the intensity of the change in the muscle itself. It is not easy to prove this statement; but if heat is produced in the muscle by chemical changes, as all admit, it cannot be denied that, possibly, the muscle, considered as a machine, may not also work in consequence of a difference of temperature, and that Carnot's theorem is also applicable to it. This statement is made in view of the well-known fact that the action of the nerve is that of a liberator of the energy of the muscle. All that is implied is that there may be a dynamic difference in the change occurring in the nerve centre from that in the motor end-plates, and that it is in consequence of this difference that there is a flow of energy from the former to the latter.

The muscular machine, however, presents certain remarkable differences from ordinary motors. This has been clearly pointed out by Hirn in several suggestive papers in *La Revue Scientifique*.<sup>\*</sup> Every machine which acts as a continuous motor can exercise an influence on another body, and then return to its original condition. It can perform work, and after the accomplishment of the work it reverts to the state in which it was before it performed the work. As an example, take a simple form of steam engine. This machine can raise in 24 hours 864,000 kilogrammes of water into a reservoir 10 metres above the lower level. If the stroke of the piston is short and the pressure on the piston is small, this work can only be accomplished by a large number of strokes of the piston. Taking 60 per minute, or 86,400 per day, each stroke will raise 10 kilogrammes 10 metres, or 100 kilogrammes 1 metre. To obtain this work, however, each time the piston rises to its full height, we must prevent the weight of the water raised by the stroke from again descending, and we must remove the pressure of the steam underneath the piston, and allow the latter to fall by its own weight, or aided by the impulse of a beam placed overhead. These arrangements secure continuous work. The reduction of pressure under the piston is

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<sup>\*</sup> *Op. cit.*

brought about by allowing the steam to return to the condition of water. The act of condensation is essential to every steam engine.

Take now an illustration of the working of a living motor. Place a series of weights (each of 20 kilogrammes) on the table. Suppose we resolve to raise each weight with the arm to a height of 50 centimetres. We seize hold of the weight and, in obedience to an effort of will, the muscles of the arm pass into a state of contraction or tension, proportional to the weight to be lifted. This condition is brought about by a flow of nerve energy along nerves from the seat of the will in the brain to the muscles. The contraction or tension of the muscles influences the jointed levers forming the framework of the arm and hand; and the force, transferred to the weight of 20 kilogrammes, raises it to the height of 50 centimetres. The work has now been accomplished, and, by another act of volition, distinct from the first, we arrest the flow of nerve energy, restrain the action of the muscles, and we then place the weight on a support intended for its reception. If we had ceased to exercise volition during the raising of the weight, or when the weight had been raised to the required height, the weight would have fallen. After placing the weight on the support intended to receive it, we loose hold of the weight, and allow the arm to descend. Hirn compares the latter action to the condensation of the steam in a simple steam-engine, or to the stoppage of the current that has been employed to magnetize a bar of soft iron. Each of the weights of 20 kilogrammes may be raised in the same way, 10 kilogrammetres of work being done in each case. Work is done by letting go each weight after it has been raised. A dynamic influence or forth-putting of energy, of the nature of which we know little, throws the muscles into a state of contraction or tension; this tension causes the dynamical effect desired, and when the work has been accomplished, the muscles return to their original state.

The action of the human motor, however, can be varied. Thus, suppose the weight to be raised is light, or, in other words, considerably within the limits of our muscular power, we can raise it easily and we can vary at pleasure the rapidity of raising it. This means that we can alter at pleasure the intensity of the volitional effort or dynamic influence that causes the muscular tension, and thus we can produce dynamic effects of great delicacy and nicety of adjustment. Another peculiarity of the human

motor is that it can readily produce a dynamic effect of the opposite kind. Thus, we can, by a voluntary effort, again seize hold of one of the weights, excite muscular tension proportional to the weight, move the weight from its support and let it descend, with a rapidity which we can vary at pleasure, by a relaxation of the muscles. When we reach the lower level, the muscles have either already become completely relaxed, or we voluntarily arrest the muscular tension; and, when the arm becomes free, it can again be raised to the height from which it started, by a new volitional effort. Few motors can in this way reverse their action. In lifting the weight we perform positive work, and in lowering it we perform negative work. Now, if work is derived from heat, the questions arise—Do the muscles absorb heat in doing positive work and give it out in doing negative work? Is the mechanical work of raising the weight done at the cost of a certain amount of heat-energy; and does the negative work of lowering the weight restore heat-energy to the muscle?

This mode of discussing the subject has been carried out with great lucidity by Hirn in the paper already noticed. It appears to me, however, that he has erred in neglecting, to some extent, the internal work done in a muscle. There can be no doubt that work is done in lifting the weight, but work is also done in lowering the weight. During the process of lowering, the muscles pass from a greater to a less contracted condition, and contraction always implies physiological work. If the muscles had not remained partially contracted during the process of lowering the weight, the latter would at once have fallen to the ground. From this point of view, so-called negative work is as much work in the physiological sense as positive work. For example, in ascending a ladder, a man raises the weight of his body, by a series of consecutive muscular efforts, a certain height. In descending, he lowers his body gradually through the same height by another series of muscular efforts. In both cases, work—that is to say, work in the physiological sense—is done, and if work is derived from heat, heat would be evolved both in ascending and in descending the ladder. In descending, less expenditure of energy is probably necessary, and consequently less heat will be evolved. The action of the nervous and muscular systems in lowering the weight, to my mind, resembles the action of a steam crane in gradually lowering a heavy load after it has lifted it to a given height. The weight descends by its own gravity, but it is

allowed to descend slowly by tension of the chain being kept up by the action of the engine.

We must, therefore, now inquire a little more minutely into the phenomena that occur in a contracting and relaxing muscle. Two phenomena are apparent, namely, contraction and an evolution of heat. It is also well known that the evolution of heat is less when there is positive external work. So long ago as 1843, Joule stated that if an animal were caused to gallop in a circus or to ascend a mountain, we may expect that in proportion to the amount of muscular effort there will be a diminution of the heat set free in the body by any given chemical action. A given chemical action occurring in the muscle, and connected with contraction, always produces an evolution of energy, one part of which appears as sensible heat and the other part as external mechanical work. The performance of mechanical work never entirely prevents a heat production; it only causes it to diminish. The investigations of Becquerel and Breschet, of Bécclard, of Heidenhain, of Fick, and of Danilewski have all demonstrated this production of heat and its relation to work. One strong objection, apart from experimental evidence, must be urged against an exclusive theory of the thermic origin of work. Whatever be the source of the mechanical work, it cannot be denied that a muscle accumulates heat when it is caused to do hard work. The muscle thus accumulates potential energy, and it seems curious that it does not utilise it if it has the power of converting some of this heat into the energy of contraction. Why, as has been asked by Chauveau, does it not convert part of this heat energy into physiological work? Why does it go on producing more and more heat? It seems strange that when a muscle develops more heat than it can transform into work, it should still continue to produce more and more heat.

Suppose we now alter our position, and regard the contraction itself as a mode or manifestation of energy. We must not forget that a muscle is elastic as well as contractile. If we attach a weight to a muscle in a state of repose the muscle becomes stretched, and when we remove the weight it returns to its former length. A muscle, in the language of physiological textbooks, is said to be feebly but perfectly elastic. Further, when a muscle is contracted a lighter weight will stretch it to the same length, and, consequently, it is said that during contraction the elasticity of a muscle is diminished. If, however, we distinguish

between the elasticity of a muscle at rest from its peculiar condition when contracted, and if we view the latter condition as an elastic state brought about by contraction; if we use elasticity in this sense, we see that it then has a dynamic value. Contractility may be said to be the cause of the dynamic elasticity of the muscle. The contractility comes first, and it calls the elasticity into action in proportion to the effort required to overcome a given resistance. This view of the question has recently been strongly put forward by Chauveau,\* and it appears to me to throw new light on this difficult subject. In developing his theory he gives, in the first place, the following illustrations to show the difference, as regards expenditure of energy, between various forms of elasticity:—

1st. Suppose we place a weight on a piston which is supported by a certain pressure of steam acting on the under surface of the piston. If we remove one-half of the weight, the piston will ascend until the steam underneath has become so much rarified as to come to equilibrium with the new charge on the piston. Work has been done, and the piston and its charge will remain in the new position without any further loss of energy, if the apparatus is covered so as to prevent the loss of heat.

2nd. Suppose a band of india-rubber fixed by one end and having a weight attached to the other end. The weight will stretch the band to a certain length. If we now suddenly remove one-half of the weight, the remaining half will be raised by shortening of the india-rubber band until equilibrium has again been established, and there is no further expenditure of energy.

In both of these cases the arrest of the free play of the force of an elastic body supports a weight, and thus performs mechanical work. The tension of the elastic body is exactly equal to the weight to be supported, and no external energy requires to be supplied for keeping up the equilibrium.

Now take the case of a muscle. Suppose we hold a weight in the hand by keeping the forearm flexed by the action of the biceps muscle at a certain angle and rigidly fixed, and also that we do not alter the volitional effort put forth with the view of

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\* Chauveau: "Du Travail Physiologique et de son Equivalence." *La Revue Scientifique*, 1888. Also, "Le Travail Musculaire et l'Energie qu'il représente." Paris, 1891.

supporting the weight. If we now suddenly remove a part of this weight, the muscle will raise the remainder up to a certain height, and the upward movement will cease when the muscular tension descends to the value of the weight still remaining on the hand. It is an essential condition of the experiment, however, that nervous action does not, in the meantime, alter the amount of elasticity which it at first called forth in the muscle. The elasticity of the muscle in this experiment appears, on a superficial examination, to play the same part as the elasticity of the steam, or as the elasticity of the india-rubber band. But there is a remarkable difference between the two cases.

Suppose the weight has taken up the new position in each of the three experiments under consideration. The elasticity of the steam and the elasticity of the india-rubber maintain this position without further loss of energy; but the elasticity of the muscle is maintained by chemical changes going on in its substance in connection with the physiological state of contraction. These chemical changes constitute physiological work; and it follows that the elasticity is kept up by physiological work. The mere maintenance of the weight at a certain height, while it may not be work in the physical sense, is truly work in the physiological sense, as there is a constant expenditure of energy. Thus, the behaviour of the muscle, as regards the maintenance of its elasticity, is quite different from that of either the steam or of the india-rubber band. The fact that a feeling of fatigue slowly comes on, if the weight be held up for a sufficient length of time, proves that changes are occurring, not only in the muscle, but also in the nerve centres, whence emanates the nervous energy that maintains the contraction of the muscle. But even when a muscle has no weight to lift, it does work in contracting. The proof of this is that when a muscle contracts, whether it lifts a weight or not, the flow of blood through it is accelerated, and the absorption of oxygen and the elimination of carbonic acid are increased. We see, then, that when a muscle sustains a weight by its elastic tension, there is a continual consumption of energy, because the elasticity is created or is brought into play by the contractility of the muscle. Contractility may therefore be regarded as a special mode of energy, directly related to the chemical phenomena occurring in the muscle. In a muscle the phenomena may be conceived to be as follow:—(1) Chemical changes, which liberate energy; (2) this energy is directly converted into con-

tractility; (3) this part of the process, the bringing about of contractility, is true physiological work; (4) the immediate effect of the contractility is to develop the elasticity which, in turn, accomplishes the mechanical work of lifting a weight or of overcoming a resistance; (5) the result of the physiological work (contractility producing elasticity) is to perform external mechanical work, along with the evolution of heat arising from the molecular changes upon which contractility depends.

Thus, instead of supposing that the chemical changes liberate energy entirely as heat, and that a portion of this heat is converted into mechanical work, the remainder appearing as sensible heat, it seems more reasonable to hold that at least a portion of the chemical energy is resolved at once into physiological energy, or, in other words, into contractility. The sequence of events may thus be expressed:—(1) Potential chemical energy changed into kinetic chemical energy; (2) actual chemical energy changed into internal physiological work, or contractility; and (3) the internal physiological work of contraction converted into sensible heat, with or without external mechanical work. From this point of view, the production of heat must be regarded as the final, and not as the first, link in the cycle. When the production of physiological work is very active, a large amount of heat is finally evolved, and if it does not escape from the body with sufficient rapidity, it accumulates to such an extent as to be positively injurious. Thus, animals hunted to death die with symptoms resembling those manifested by animals which have had their temperatures raised by five or six degrees. The animals which bear severe muscular exercise with comparative impunity are those which lose heat most readily. The heat thus produced is not, however, to be regarded as absolutely useless. A certain mean temperature is one of the conditions of existence of warm-blooded animals. Thus, a living motor, a muscle, produces heat, and this is one of the conditions of its own existence.

Various attempts have been made to measure the relative amounts of work and of heat produced by a muscle, considered in relation to the chemical operations of which it is the seat. One of the most recent of these attempts is that of Chauveau and Kaufman, made in 1887.\* The problem was as follows:—To

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\* Chauveau : *Comptes Rendus*, t. cv., p. 296; also, "Le Travail Musculaire," *op. cit.*, p. 263.

determine, for a given weight of living muscular tissue in normal physiological conditions: (1) the quantity of blood flowing through it in a unit of time for purposes of nutrition; (2) the weight of oxygen absorbed by the tissue, together with the amount of carbonic acid produced in a unit of time; and (3) the weight of the substances furnishing the carbon of the carbonic acid. The muscle chosen was the elevator of the upper lip of a horse. This muscle is accessible; it can easily be studied at rest or when in action; and, from the arrangement of the vessels, the blood passing into it can be readily measured and collected for the analysis of its gases. The "specific activity or the co-efficients of the nutritive and respiratory exchanges" can be calculated from the data obtained by experiment, and stated for one gramme of muscle and one minute of time. The results are highly instructive. Each gramme of muscle was traversed in one minute by .8 gramme of blood which was heated from  $0.47^{\circ}$  to  $0.49^{\circ}$  C. Supposing the capacity of blood for absorbing heat to be the same as that of water, the heating effect amounts to from .000375 to .000392 calorie. These figures represent the thermic equivalent of the work of the muscle, per gramme; or, in other words, the amount of energy required to give the necessary elasticity to the muscle. Can we account for this evolution of energy by considering the chemical phenomena happening in the muscle? Each gramme of muscle absorbs in one minute, when it works, .00012 gramme of oxygen *above* the amount absorbed at rest. Supposing all this oxygen went to form carbonic acid by uniting with carbon, the amount of heat so produced would be .000365 calorie, a figure remarkably near that obtained by the other method (a mean of .000383).

Take, finally, the amount of carbonic acid in the blood escaping from the muscle, and from it calculate the amount of heat evolved in its formation. The amount of carbonic acid per gramme per minute is .00020 gramme, representing in heat .000440 calorie. This is greater than .000365 by .000075—that is to say, the respiratory

quotient  $\frac{\text{CO}_2}{\text{O}}$  is greater than unity during muscular work. As a

rule, the respiratory quotient is less than unity when a muscle is at rest.

In this remarkable experiment, no account has been taken of any other chemical phenomena in the muscle except the production

of carbonic acid, because our knowledge of these phenomena is very obscure; but if we were able to take them all into account, the balance between the energy set free by the chemical exchanges, and the heat produced would be complete. We may take it, then, that the thermic equivalent of the physiological work of one gramme of the elevator muscle of the lip of a horse is in one minute 000380 calorie. This is the energy set free by one gramme in one minute, when the muscle had only to move itself. When it was caused to do external work, the energy appearing as heat was 000335 calorie, so that the external work absorbed 000045 calorie. The ratio then of the total physiological work to the external mechanical work was about 8 : 1; or, in other words, to produce a given amount of work, the muscle was supplied with about eight times more energy than was required for this work. According to Chauveau's theory, all the physiological work is required to produce the requisite amount of elastic tension, but this elastic tension only utilises as work one-eighth part of this energy, the remaining seven-eighths going off as heat.

It is thus shown that the energy consumed in producing the elastic tension of the muscle is much greater than that appearing as effective work. We have no right, however, to assume that the ratio of 8 : 1 is constant, even for the same muscle at different times, and still less for muscles having different mechanical arrangement of their fibres. Finally, there is a striking difference between the behaviour of a band of elastic india-rubber and a muscle. To develop and maintain the elasticity of the muscle, a much larger amount of energy is consumed than to develop the elasticity in the india-rubber band. Chauveau states that to give an elastic band a tension necessary to raise a weight of 1 kilogramme to a height of 1 decimetre, energy must be expended to the extent of  $\frac{1}{4256}$  calorie; while an equal amount of muscular tissue would only acquire the same elastic tension by an absorption of *eight* times more energy, or  $\frac{1}{532}$  calorie.

So long ago as 1869, Professor Fick, of Würzburg, stated that the amount of energy transformed into mechanical work by a muscle was about 33 per cent. In 1878 he announced that more elaborate and accurate experiments had obliged him to reduce the estimate to 25 per cent.\* His experiments were made on isolated

\*A. Fick: "Experimentellen Beitrag zur Lehre von der Erhaltung der Kraft bei der Muskelzusammenziehung," 1869; also "Ueber die Wärmeentwicklung bei der Muskelzuckung," 1878.

muscles of the frog, and to some extent were vitiated by the conditions in which the muscles were examined. Chauveau has reinvestigated the question by ingenious experiments on the muscles of living men in natural conditions. These experiments are fully described in the elaborate work recently published, entitled "*Le Travail Musculaire et l'Énergie qu'il représente*," a work which will sustain the fame of the great French physiologist. These researches oblige Chauveau to reduce Fick's estimate and to give the total effective work as only from 12 to 15 per cent. This is less than was expected, and it indicates that, contrary to what is often stated, a single muscle, considered as a machine, returns about the same effective work as a steam engine of the best construction.

How is this statement to be reconciled with the calculations based on the results obtained by the calorimetric observations of Hirn already described, in which he measured the total heat evolved by the body of a healthy man while engaged in performing mechanical work? The amount of efficient work was stated to be at least 17·4 per cent. of the total energy. This is somewhat greater than the results reached by Chauveau's method, but the difference is not striking, and it may be at least partially accounted for by errors of experiment. We must also bear in mind that there may be a considerable difference between the effective action of a muscular machine, made up of many muscles moving a complicated system of levers, and a single muscle. Work is done by such a machine by mechanical arrangements, all of which may have the effect of utilising, in the best possible way, the available energy.

Let us now endeavour to obtain a glimpse of the phenomena happening in a living muscle. In the first place, we must note the fact that even while at rest it consumes oxygen, produces carbonic acid and other substances—some nitrogenous and others non-nitrogenous,—and gives off heat. It is supplied by a nerve, the fibres of which, on the one hand, originate from nerve cells in the brain or spinal cord, and, on the other, terminate in the individual fibres of the muscle. When the nerve cells act, a current or change of some kind is transmitted along the nerve fibres to the fibres of the muscle; and this current of nervous energy excites chemical changes in the muscle-substance, one result of which is a larger consumption of oxygen, and a larger

production of carbonic acid and of other waste substances. These chemical changes liberate energy in the form of a movement called a contraction, and at the same time there is an evolution of heat accompanied by certain electrical phenomena. The contraction, no doubt, is the result of the chemical changes; the molecules, or molecular fibrous network of the contractile substance, taking up new positions, and the fluid in the interstices of the fibrous network, or bathing the molecules, streaming in such a way that the muscular substance becomes more tense and develops elasticity in proportion to the resistance offered to the contracting muscle by its attachments to bones. As already pointed out, the energy appears as heat and movement, and the old question again presents itself:—What is the relation of the chemical phenomena to the energy thus liberated in a two-fold way?

It seems clear that the muscle cannot transform heat into movement. It is the seat of chemical changes, and internal or physiological energy is set free. This energy is transformed into contraction of the muscle-substance, and this, in turn, develops elasticity (the elasticity of contraction, as we may term it), and, by this elasticity of contraction useful external mechanical work is accomplished. Associated with this contractile and elastic state, we find the remainder of the energy appearing as sensible heat. The elasticity is, from this point of view, a passing or transitory form of energy. None of the energy set free by the chemical changes is useless. Its dissipation is regulated by the internal work of the muscle—that is to say, by the effort which the muscle makes to change its form when it is obliged to overcome resistance. This change of form produces a special elastic force, the value of which is determined by the amount of muscular shortening, and by the resistance to be overcome, and the remainder of the energy not used up in performing external work appears as heat. Such is the most modern theory advanced to explain the action of “Muscle as a Transformer of Energy.”

II.—*On Limes and Cements.* By ALEXANDER M'ARA.\*

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[Read before the Architectural Section, 14th December, 1891.]

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THE subject of limes and cements, to be treated exhaustively, would occupy more time than can be given to it in a paper such as this. I have therefore endeavoured to treat more particularly of those limes and cements with which we are more immediately concerned in Glasgow and district. These are—(1) the Scotch and Irish limes in common use, and classed as rich or fat limes, many of them having no “setting” or binding quality in themselves, nor when mixed with sand; (2) Portland and Roman cements; (3) hydraulic lime, known as Arden lime, and so named after the farm on which it was first quarried.

## COMMON LIMES.

The common rich or fat limes, which are non-hydraulic, require to be slaked with water, either by sprinkling or by immersion, some time before being used. The local method is to throw water on the shells and cover them with sand, which reduces the lime to a state of hydration, but frequently, as I hope to show you, in a very imperfect and partial manner, and portions of the lime continue to slake long after the mortar has been used. The ancients were accustomed to slake their limes by immersion. Under water they remain in a plastic state, and gain in quality as mortars by being allowed to remain immersed. Plinius states, that the Romans were so convinced of this fact that the ancient laws forbade the use of lime, unless it had been slaked for three years, and that it was owing to this thorough slaking that their works were not defaced by cracks or crevices. Alberti mentions, in the eleventh chapter of the second book, that he once discovered in an old trough some lime which had been left there five hundred years, as he was led to believe by many indications around it, and that the lime was as soft and as fit to be used as if it had been recently made.

Common mortar made of rich lime hardens very slowly, and only by the evaporation of the water of the mixture, and by the absorption of carbonic acid from the atmosphere, with which it forms a crystalline carbonate of lime. This process, however, is

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\* For titles of works referred to see p. 54.

so slow, that it gave rise to the French proverb (quoted by Pasley), that "Lime at a hundred years old is still a baby;" and there is a similar proverb among Scotch masons—"When a hundred years are past and gane, then gude mortar turns into stane."

It has been ascertained that with rich lime mortars, the carbonic acid penetrates about one-tenth of an inch into the joint in the first year, forming a skin or film which opposes the further absorption of carbonic acid, except at a decreasing ratio, so that, where there is a mass of masonry, the lime remains soft for an indefinite period. In illustration of this several cases have been cited, amongst others one by General Treussart, who in the year 1822 had occasion to remove one of the bastions erected by Vauban in 1666. After these 156 years the lime in the interior was found to be quite soft.

Dr. John, of Berlin, mentions that in removing a pillar of 9 feet diameter in the church of St. Peter, Berlin, 80 years after erection, the mortar was found to be quite soft in the interior.

General Pasley mentions several instances at Dover Harbour, and at Chatham Dockyard, the latter in particular, when part of the old wharf wall was pulled down in the winter of 1834. The workmen were obliged to blast the brickwork fronting the river, which had been built with Roman cement, but the backing, done with common lime mortar, was in a state of pulp; the lime used had been prepared from pure limestone or chalk. But we do not require to go so far back for knowledge of the absence of the setting quality in the rich limes, as there have been frequent experiences of it in and around our own city. While these remarks are true of the richer limes, many of our local limes are comparatively poor in carbonate, and associated with silica, alumina, magnesia, and oxide of iron, which may either be partially combined in the natural state, or enter into combination with the lime during the process of calcination, and these limes might be termed slightly hydraulic. The practice, however, has been for lime producers to show their lime as rich as possible by analysis, and for users to prefer a rich lime, for the reason that it makes a more plastic and better working mortar with the usual quantity of sand.

Now, it has been proved by experiments, many and varied, and extending over a long period, by the most eminent authorities, French, German, and English—most prominent amongst them, Smeaton,—that this preference should exactly be reversed, and that

the poorer common limes will make the best mortar, and will, in a comparatively short time, show some slight setting power, whereas the very rich limes never take band, except in so far as they return to their original condition of carbonate by the re-absorption of carbonic acid from the atmosphere, and by the slow evaporation of the water of mixture. If it does not evaporate, the mortar remains always soft. If it evaporates too quickly, the mortar falls to powder, a result which must be in everyone's experience who has witnessed the taking down of old buildings, and the clouds of dust created by the removal of every stone. An illustration has occurred to me which, I think, will make plain, even to the uninitiated, how radically bad is our system of using common lime mortars.

In preparing lime for plaster work the local practice is to slake it for at least three weeks before using. Not only so, but a particular kind of lime is selected, namely, Campsie lime, or other cool limes of the Hurlet and Campsie strata, for the reason that it is not liable to blister and deface the internal walls when finished. Now, while all this precaution is taken in regard to plastering, in making mortar for building, the lime is slaked and made up at once, and it is frequently used within a day or two. But this is not all. Limes which are unsuitable for plaster work, known as hot limes, and which, when plasterers are obliged to use, must be slaked for a period of—not three weeks—but more nearly three months before using, and are then not quite safe from blistering, are the limes mostly used for building purposes. Now, it will at once be seen that when mortars of these limes are used immediately, the unslaked particles go on slaking for a long time, drying up the moisture, and leaving only a friable dust in the joints. This should help us to understand the old Roman law which enacted that lime should be slaked for three years before using. If three years should seem to us an absurd time, I am satisfied that at least three months are required to slake completely and to develop fully the qualities of many of the common limes in every-day use. Major-General Gillmore, an eminent American specialist, and a recent writer on the subject of Limes and Cements (page 190), mentions that in the south of Europe it is the custom to slake the lime the season before it is to be used.

Burnell, on the "Making of Mortars" (page 66), says:—"The making of mortar comprehends the slacking of the lime and the mixture of the ingredients worked up with it. As we have already

seen, both the former process and the nature of the latter differ, according to the nature of the lime to be dealt with. It is, however, a universal rule, in contradiction to the slovenly practice of London builders, that all limes, of what nature soever, should be reduced to a paste before being mixed with other ingredients.

"People who have not studied the action of the hydrates in a scientific and consecutive manner oppose the introduction of the previous manipulation of the lime on the score of the extra expense, and on the pretence that the lime loses in strength thereby. As to the objection of the expense, that must of course be estimated by the importance of the works. The second objection is met by observing that the rich limes require to be for a long time exposed to the air to enable them to take up the carbonic acid gas; and that, therefore, so far from losing, they gain by exposure; and, moreover, it is necessary that all their particles should be put in contact with water. If the lime be not previously reduced into the state of a perfect hydrate it is always liable to blister and to disintegrate in a manner depending upon the comminution of its particles before being employed."

Amongst the great variety of Scotch limes, those of the Hurlet and Campsie series have a reputation which has been handed down for generations. The analysis of the lime from the mines of the Hurlet and Campsie Alum Company gives the following proportions:—Carbonate of lime, 91·40; carbonate of magnesia, 3·40; carbonate of iron, 2·07; bi-sulphide of iron, ·41; alumina, ·60; silica, 1·00; phosphoric acid, ·10; coaly matter, ·80; water, ·10. We find here, then, in the first place, that the Campsie limestone is not so rich in carbonate of lime as is generally supposed, and that in itself would indicate slightly hydraulic properties.

Magnesian limestones are hydraulic, and when we find carbonate of lime replaced by carbonate of magnesia to the extent of 3·40, this emphatically asserts the semi-hydraulic nature of this lime. The quantity of magnesia present is about double that to be found in any other of the limes used locally. The iron constituents are also of the maximum, and give a dark brown colour to the shells. Magnesian lime slakes readily without giving off much heat, and I think I am correct in saying that this is a characteristic of Campsie lime, and it does not give off so much heat in slaking as the average of limes, while at the same time it slakes very freely. This lime has been wrought from time immemorial. At first it was got in open-cast workings, but for a long time it has all been

mined. There is a legend that Glasgow Cathedral was built with Campsie lime, and in all probability it is correct.

Irish rich lime, as used by us for the finishing coat of plaster work, is slaked by immersion as the Romans are said to have prepared their limes, and this is called "putty lime." This putty lime, prepared by immersion for a longer or shorter period—seldom less than three weeks—before being used, is laid on in a very thin coat, and gives a hard skin to the surface. This hardness, I believe, is largely, if not wholly, due to the fact that the lime is laid on in a thin layer on the top of other lime that has already absorbed carbonic acid from the air. This thin layer becomes harder than the main body of the plaster.

Where it is required that plaster should dry quickly, it is a common thing in some places to put a fire of coke in a chauffer in the centre of the room for the purpose of drying it; but the carbonic acid given off by the coke plays a very important part in the hardening, as well as does the heat in drying.

The whole process of preparing plaster lime and laying it on the walls in thin coats, with a considerable space of time between the coatings, is conducive to the ultimate hardness of the whole. The lime being first slaked and then soured, all this time being exposed to the carbonic acid of the atmosphere. Again, each coat is long exposed to the same influence before being covered with the next, altogether in marked contrast to the system of using the mortar in building.

It may here be noted that while the practice is rather to overburn ordinary limestones to insure calcination all through the pieces, yet the best results are got from lime rather underburnt. In the first place, it slacks more freely and with less tendency to blister afterwards, and, if a hard kernel should be left in some pieces, this is amply compensated by the absence of too highly burnt or even fused parts in the other case; and, as has already been shown, the retention of a small percentage of carbonic acid in the lime confers hydraulic or setting properties to some extent upon the mortar.

It will have been seen from the foregoing remarks on the common limes how very unsuitable for works of a permanent character are our common limestones, especially the purer varieties; and this unsuitability is greatly intensified in regard to all works where the binding material is required to resist the action of water. It was, therefore, but fitting that in a maritime

nation, requiring to erect all round her shores works in the form of docks, harbours, lighthouses, &c., for the accommodation and safety of her shipping, the true source of the hydraulicity or water-resisting powers of mortar should first be discovered; and, although Smeaton did not invent any particular cement, he was the first to discover that the hydraulic properties of lime depended upon the combination of the lime with clay. To this circumstance the discovery of cements is due, and the marvellous advance we have made in all matters relating to hydraulic engineering has been rendered possible. The history of Smeaton's search after a mortar capable of resisting the inroads of the sea, which he undertook preparatory to building the Eddystone Lighthouse, is of much interest, and his discovery is really the genesis of an important industry: important in itself, as regards the many thousands employed in the actual manufacture and use of cement, but more important still in regard to its influence on the trade and commerce of the world, and the possibilities which it has afforded for their development.

General Pasley, himself eminent amongst scientific authors, who studied and experimented on this subject, says of Smeaton:—"Of all the authors who have investigated the properties of calcareous mortars and cements from time immemorial to the present day, our countryman, Smeaton, appears to me to have the greatest merit; for although he found out no new cement himself, he was the first who discovered, in or soon after the year 1756, that the real cause of the water-setting properties of limes and cements consisted in a combination of clay with the carbonate of lime, in consequence of having ascertained, by a very simple sort of chemical analysis, that there was a proportion of the former ingredient in all the natural limestones which, on being calcined, developed that highly important quality without which walls exposed to water go to pieces, and those exposed to air and weather only are of comparatively inferior strength.

"By this memorable discovery, Smeaton overset the prejudices of over 2000 years, adopted by all previous writers, from Vitruvius in ancient Rome, to Belidor in France, and Sempie in this country, who agreed in maintaining that the superiority of lime consisted in the hardness and whiteness of the stone; the former of which may, or may not, be accompanied by water-setting or powerfully cementing properties, and the latter of which is absolutely incompatible with them.

"The new principle laid down by Smeaton, the truth of which has recently been admitted by the most enlightened chemists and engineers of Europe, was the basis of the attempts made by Dr. John, at Berlin, and by Vicat, in France, to form an artificial water lime or hydraulic lime in 1818, and of mine [General Pasley's] to form an artificial cement at Chatham in 1826, to which I was led by the perusal of Smeaton's observations, without knowing anything of the previous labours of those gentlemen on the continent or of Mr. Frost, the acknowledged imitator of Vicat in this country. Every author on lime or cements that I have met with followed the authority of Vitruvius, until after the middle of the last century, when Smeaton came into the field and pointed out the inaccuracy of his doctrines, in the same manner as Bacon had set aside the implicit belief in the doctrines of Aristotle in matters of philosophy."

#### POZZUOLANA.

Smeaton's first experiments were in the direction of giving hydraulicity to common fat limes by using pozzuolana instead of, or in conjunction with sand, and he ultimately fixed on a lime of the blue lias formation from Aberthaw.

Natural pozzuolana is a calcareous or argillaceous earth, principally composed of silicate of alumina, with a small percentage of lime, iron, magnesia, &c. It takes its name from the village of Pozzuoli, near Vesuvius, where it is still worked, as well as in other parts of the provinces of Naples and Rome, especially at Bacoli and Vesuvius, where, from their position for facility of shipping and vicinity to the railways, they are the most important. These are all open workings. The pits at Bacoli send away 10,000 tons annually, but could produce 50,000 tons. The price is about 10d. per ton. This pozzuolana is found in beds sometimes 60 feet thick, in a powdery state, ready for mixing with lime for mortar, which it renders hydraulic. The analysis gives silica, 47·66; alumina, 14·33; magnesia, 3·86; oxide of iron, 10·33; lime, 7·03; alkaline and volatile matter, 4·13. Burned clay was also used with the same effect, and this was styled artificial pozzuolana.

The use of pozzuolana is not unknown in Glasgow, although it has not been customary to designate it by that name. I refer to

what is known as "black sand" from the foundries. There is a conflict of opinion as to its value in mortars made of common lime. I can myself give two notable instances of it.

When building my present works on the site of what had previously been a foundry the black sand was plentiful, and at hand, and was used in the mortar. Sometime afterwards I had occasion to cut a doorway through a wall, when the mortar was found to be as difficult to cut as the bricks.

Again, when putting in an engine seat lately, the foundations of the kilns were cut and a portion of the concrete taken out, a piece of which is now exhibited. This concrete was rather a curious mixture in the light of the present day, being composed of Scotch common lime, small Irish lime, black sand, and broken stones or bricks. I have no doubt whatever that the elements which imparted the hydraulic power to the mass were the black sand and the ashes and dust in the small Irish lime. Portions of the rich Irish lime did not mix with the mass, and still remain soft, as will be seen on examining the samples of concrete. It would seem that the loamy sand being calcined in contact with molten metal, and probably by its retention of some portion of the iron, becomes a valuable artificial pozzuolana, and confers hydraulic or "setting" energy to fat lime mortar.

Mine dust is another valuable local pozzuolana, and is well known to confer hydraulic energy to common limes. In this material there is a double action, both the burned clay and the iron particles having the power of conferring hydraulicity on lime, while the combined action goes to produce the important results so familiar to those who have used these materials.

These pozzuolanas, or their equivalents, seem to be found in many countries. Pasley mentions that pozzuolanas, both natural and artificial, have been in common use in the south of Europe since the time of the Romans, though the latter has been but little used in this country, and the former not at all, until Smeaton first introduced it in building the Eddystone Lighthouse.

Professor Scorgie, in an excellent little work on "Building Materials," recently published, and specially arranged for the use of engineering students of the Poona College of Science, mentions two substances used in India—namely, "red ochre" and pounded brick, termed "surkhi." These substances all tend to make rich limes hydraulic, and Vicat, in summing up in regard to the various ingredients suitable for making mortar, after an experience of forty

years, says :—"To a certainty, we shall be further off the best, and that in a greater degree, the more completely the combinations made use of tend to invert the scale which places the 'very energetic' pozzuolanas opposite the very caustic rich limes, and the 'inert' sands opposite the eminently hydraulic, very mild limes.

"Lastly, we shall have done the greatest mischief possible when we have united together rich limes and any kind of sands. Such is the language dictated by a comparison of facts. It is necessary to add that when we meet with substances of qualities intermediate between those which constitute the categories given above, we must use medium proportions." Vicat, quoting Dr. John, of Berlin, says :—"We have often discovered the nature of the lime made use of for these ancient mortars by the particles of lumps of the lime mixed with the sand, and we have generally found it to be either rich or very feebly hydraulic." It results from these facts that, after a maceration of 600 or 700 years, favoured by the constant humidity of the soil under which they are buried, the mortars of rich lime harden. The term is rather long, it will be admitted, for all practical purposes.

I shall just mention one other early source from which hydraulic lime was and still is obtained. In some countries the ashes, which fall through the grates of lime-kilns, were and still are carefully collected, and used for mixing with rich lime, with the effect of rendering it hydraulic to a great degree. They are found to be mixed with minute portions of lime, and it is, doubtless, to their presence, along with small underburnt pieces of limestone, that we may attribute much of their useful action. I have tested and proved this with the small Irish lime, which consists of the riddlings from what we call the picked limeshells. This lime, however, must first be thoroughly slaked; then ground to a mortar in a panmill—adding two or three parts of sand. Small lime so treated is, undoubtedly, hydraulic to a degree.

In Belgium it is very largely and successfully used for canal and river works under the name of "Cendree de Tournay." Its hydraulic properties appear to arise from the mixture of the lime, in a very minute state, with the residual silicate of alumina of the cinders, and from the carbonic acid of the underburnt pieces of limestone. To the choice of such materials, as I have enumerated, for hydraulic mortars, our engineers were limited, until the discovery of Roman cement, by Parker, in 1796, followed by that of Portland cement about 1824.

## ROMAN CEMENT.

Treating briefly of Roman cement, I have to say that the first hydraulic lime or cement, of any real value, known in this country was that obtained from the septaria nodules of the Kimmeridge and London clay formation, found in the Island of Sheppy, discovered and patented by Mr. Parker, of London, in 1796, and absurdly called Roman cement. Subsequently, Mr. Frost made a cement of the same nature from the same raw materials, found at Harwich, on the coast of Essex. While London was, and still is, confined to that uncertain and limited source of supply for Roman cement, Glasgow was favoured by the discovery, about fifty years ago, of the same mineral in abundance, quite close to her borders. It was discovered by the late Mr. Charles Macintosh, of "waterproof" fame, who then owned and resided at Crossbasket, near East Kilbride. On working the limestone at Calder Glen, the cement stone had to be removed, and the custom had been to break it up, and mend the roads with it. When in England on one occasion Mr. Macintosh wrote to his foreman to lay the stone aside, and when he returned he had this hard stone burned and pulverised, the result being a cement similar to that which Parker had discovered in 1796. It is believed that Mr. Macintosh, while in London, had seen the stone which was used for making the Roman cement there, and found a resemblance in some respects. He named it Roman cement, and it was sold at something like 30s. per barrel. At the present day the price is about a fifth or a sixth part of that figure. Mr. Macintosh continued to work this cement for some time, grinding and sifting it in his Cudbear Works in Ark Lane. He afterwards sold the Crossbasket estate to Sir William Maxwell, who, after working the cement for a time, leased the minerals to Messrs. John Brown & Co., by whom the manufacture of this Roman cement was continued for about thirty-five years, down to 1882. Roman cement stone was afterwards found at Orchard, near Giffnock, and near Barrhead, where I am at present working the same cement under a lease of the late Lord Glasgow's minerals. This seam is three feet thick, and the analysis shows the cement to contain—lime, 48·44 per cent.; silica 17·90; alumina, 12·12; iron peroxide, 9·68; magnesia, 1·92; alkalis, 1·80; carbonic acid, 7·15.

Roman cement, in its "setting" action, is very similar to Portland  
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cement, and although its tensile strength is less than that of Portland, its specific gravity is also much less, the weight per bushel being only about 75 lbs. as against 112 lbs. for Portland, so that a half more may be used in the matrix to bring up the strength without increasing the cost, leaving the relative price as 22s. is to 35s., or only two-thirds that of Portland. Again, Roman cement is entirely exempt from the objectionable element of free or uncombined lime attaching to Portland cements, and there is no risk from "blowing," the lime and clay having been incorporated by Dame Nature in a perfect manner.

#### ARDEN HYDRAULIC LIME.

The natural hydraulic lime known as Arden lime is certainly the most valuable in this part of the kingdom, taking quality and price into account, and had the early makers of this material recognised its real character and treated it as what it in reality is—a natural slow-setting cement,—it would have occupied a very different position at the present day as a cementing material in building construction.

In its position amongst the minerals, the stone which yields this lime appears to be a sedimentary limestone that has been formed by being deposited from water which held it in solution. It is very fine-grained, and contains almost no fossils, scarcely the trace of a shell to be seen, except at the tops and bottoms of the divisions, which are four in number, and in all from 9 feet to 12 feet thick. The layers differ slightly in their richness of carbonate, so that to have the lime equal in quality the layers have to be carefully blended; but in this there is no difficulty, as the different seams are all worked together. Some of the layers will slake with water after calcination, others will not, at least till after very long exposure. When first worked it was the custom not to grind, but to slake, the lime when it was hot in the kilns. In this way only a portion of it could be utilised. The grinding was only commenced at a comparatively recent date, and that very imperfectly, leaving a residue of 35 to 40 per cent. on a sieve of 2,500 meshes to the square inch, instead of about 10 per cent., as in the case of Portland cement. No doubt a portion of this large residue will slake when mixed with water into mortar, but at periods varying from hours to—it may be—years; so that it is obvious that fine grinding is a necessity, and the "setting" properties are not fully and safely developed unless the whole is finely pulverised. To be

sure, the expense to the manufacturer is increased in proportion to the fineness, so much so, that to reduce the lime down to a residue of 15 per cent., instead of 35 per cent., will quite double the cost of grinding; but against that you have a reliable natural cement. On the other hand, if coarsely ground, the covering capacity, and consequent strength of the mortar or concrete are very much less.

Regarding the process and cost of the manufacture of this natural cement as compared with those of the artificial product known as Portland cement, as already mentioned, the former is a natural compound of lime, silica, and alumina. In the latter these ingredients are artificially united. The first cost of the raw materials—the chalk and clay—of the Portland is considerably less than that of Arden hydraulic. The chalk is more easily quarried than the hard limestone, besides which the thickness of the chalk at the working face is three or four times that of the Arden limestone; thus the extra cost of Portland cement is accounted for in the artificial, mechanical, and chemical combination of the constituent parts. In my process the lime shells from the kiln are ground in the same way as the clinker of Portland cement. Beginning with a stone-breaker, the lime passes thence to a pair of chilled crushing rollers, and finally to the millstones, after which the powder is carried by screw-conveyor and elevator to a rotary screen, 12 feet by 4 feet, covered with wire cloth, which retains and returns to the millstones any residue in excess of the required fineness. Sifting I hold to be a very important part of the process, although it has not been practised by any other makers of this hydraulic lime. It is impossible to have the millstones so perfect that they will not pass a few large particles. The testing of this hydraulic cement should be conducted on the same lines as the artificial product known as Portland cement. It has been my practice so to test it, and the results obtained are as follow:—

Tensile strength per sq. inch, at 7 days,		80 lbs. to 100 lbs.	
Do.	do.	1 month,	150 „ 200 „
Do.	do.	3 months,	250 „ 350 „
Do.	do.	6 „	350 „ 400 „
Do.	do.	1 year,	450 „ 500 „
Do.	do.	2 years,	500 „ 600 „
Do.	do.	3 „	600 „ 700 „

These figures show a steady and progressive increase of tensile strength. At six months it is equal to that required of Portland

cement in a week—namely, 350 lbs. to the square inch, continuing about the same ratio of increase till at three years it doubles that figure, and reaches 600 to 700 lbs. Mr. Faija, of London, in his work on “Portland Cement,” says, at page 41—“A cement that increases only, say, 10 per cent. in strength between 7 days and 28 days, has practically told its history. And it is known within a fraction the ultimate strength to be expected of it, but it may fairly be expected that a cement whose increase of strength in the same time amounts to 25 or 30 per cent., will continue to increase for a considerable period, and that its ultimate strength will be great. Given, therefore, that a minimum strength at the expiration of seven days is specified, the increase in strength during the next three weeks is one of the surest guides to the ultimate value of the cement.” Arden hydraulic lime, as we have seen, increases 80 to 100 per cent. between the 7th and 28th days, and at three years 600 to 700 per cent. This goes a long way to prove two things—1st, that Mr. Faija is correct in his hypothesis; and 2nd, that this slow-setting natural cement amply fulfils its early promise.

The briquette, from which these results were obtained, was of the 1-inch section. By using  $2\frac{1}{4}$ -inch section, the same tensile strength is not arrived at for a much longer period. This would show, on the other hand, that, in practice, the mortar joints, being under half-inch thick, will gain strength at a quicker rate than even by the 1-inch section briquette.

During all the years I have been manufacturing Arden hydraulic lime I have never observed one instance of deterioration, whether briquettes were kept dry or under water; whereas I have noticed many instances of Portland cement briquettes disintegrating after the lapse of a few years, and crumbling away by the subsequent bursting-up of the free lime. In proof of this I refer you to the samples of both now exhibited.

#### BLUE LIAS LIME.

The Blue Lias lime formation is that from which hydraulic lime is principally obtained in England, and it is found over a wide area—at Aberthaw, from whence Smeaton drew his supplies for the Eddystone Lighthouse, and at Rugby, where it is also manufactured into Portland cement. This lime, while it has excellent hydraulic properties, can hardly be classed as a cement.

It slakes easily with water, while the Arden lime will only partially slake, and that in a very sluggish manner, and the bulk of it will not slake any more readily than Portland cement clinker.

The lias lime manufacturers, in their instructions as to its use, say:—"In using blue lias lime for mortar, &c., great care is required in reducing it to extreme fineness, and it is usually done by two ways: slaking or grinding. When slaked, lias lime may be kept with advantage for a week or ten days, but the time depends entirely on the care taken in slaking; and so important is this that mortar may be made having a great adhesion or only a small one." As I have shown, there are no such risks attending the Arden hydraulic, as it is all ground, not slaked.

Regarding the ground lias the manufacturers say:—"This lime, though reduced to powder by machinery, will, upon being treated with water in mortar-making, throw off heat, expand, and slake into finer powder. Until this has taken place, and it has been re-made with the proper proportion of sand, it is dangerous to use." Arden hydraulic, properly manufactured, does not throw off any more heat in mixing with water than the average of Portland cements. It will be seen from these comparisons that the Arden is a more reliable hydraulic lime than the lias.

#### HYDRAULIC PLASTER LIME.

I have lately introduced a specially-prepared hydraulic plaster lime, having the Arden as a basis. The object aimed at was to produce a plaster lime which would give a hard solid body of concrete, slow-setting, and suitable for plastering purposes, and which could be used immediately, and with perfect freedom from blistering. That I have succeeded is abundantly proved by the fact that it is growing into extensive use. It will be found as good in damp situations as any cement, although slower-setting. It is also to a large degree fireproof, and in that respect will, I believe, be found in the front rank with any fireproof plasters yet offered as such.

The following is from a recent article in a London publication connected with the building trade:—"In case of fire, common lime mortar is quickly dried out, and the carbonic acid that has been absorbed is expelled, leaving the mortar a crumbling mass that has nearly or quite lost its cementing properties. Hydraulic

lime has inherent 'setting' qualities, and the water of mixture is retained and becomes the water of crystallisation. This hydraulic property renders it peculiarly valuable in many varieties of work, notably in foundations, cellars, bath-rooms, kitchens, and laundries, as moisture only serves to harden it. A mixture of common lime and cement has sometimes been used to give mortar hydraulicity and strength. This forms a hydraulic lime mortar, but the combination is only mechanical, whereas, in natural hydraulic lime mortar, the combination is strictly chemical, or a true silicate of lime, the only mortar-making material that can endure for ages the disintegrating effects of the sudden and extreme variations of temperature and other changes in our climate. In case of fire, the extreme heat will only serve to glaze hydraulic lime over, and cement the material together all the more firmly. In a few days after it is used hydraulic lime begins to change, and gradually hardens. At the end of a month it will appear like cement, and in time it will become as hard as the material which it binds together. Hydraulic lime, as prepared for the market, is finely pulverised, and needs only to be mixed with sand and water to be ready for use. It requires no slacking; will keep for a year or more in barrels or sacks without deterioration; it has all the smooth and slow-working qualities, and the sand-carrying capacity of common lime, and when used for plastering requires no hair, and does not 'pop out' or 'blister.'" Otherwise this hydraulic plaster lime has been found to answer well. A better job has been got with it, and in much less time, while the preparing and working-up of the material have been found more convenient. One great advantage in the use of this plaster lies in the fact that the plastering of a building can be completed in one-third of the time required by the ordinary method.

#### PORTLAND CEMENT.

This material, absurdly so called from a fancied resemblance to Portland stone, was first manufactured in England in 1824. Since then the industry has made immense strides, and at the present time the annual output in Europe exceeds 20,000,000 tons; England, 8,300,000; Germany about the same; France, 1,800,000; Russia, 900,000; Belgium, 800,000; and in the United States of America, 3,000,000. Portland cement is simply an artificial hydraulic lime, and its manufacture is based strictly

on the lines laid down by Smeaton—namely, the combination of lime and clay. Any advance on his theory has been confined to the improvement in the methods of incorporating the lime and clay. I shall not attempt to go fully into the subject of Portland cement, indeed it is less necessary to do so from the fact that so much is being constantly said as to its manufacture and qualities; and yet there is nothing new of any practical importance since the papers read by Scott and Redgrave, and by Grant, with discussions thereon by the most eminent authorities of that day, including manufacturers, engineers, and scientists, and recorded in the *Proceedings* of the Institution of Civil Engineers, vol. 62, which, doubtless, is familiar to many present.

The principal seats of manufacture in this country are on the Thames and Medway, and also at Newcastle, the lime used being chalk, both white and grey.

Portland cement is also made from the lias lime at Rugby, in Warwickshire, at Stockton, and in other parts of England. In America, Portland cement is manufactured from carboniferous, argillaceous, and magnesian limestones of endless variety, obtained in many districts all over the States. In France, Germany, and Austria, it is also manufactured from a wide variety of raw materials, having carbonate of lime for their basis.

The cement, however, mostly used in this district, owing to the cheapness of freight from London, is that made on the Thames and Medway from chalk and clay. The process is briefly as follows:—The chalk and clay are mixed in a wash-mill, and this mixture, technically known as “slurry,” is conveyed to millstones, going at a high speed, and passed through these in a semi-liquid state, to ensure that any harder parts of chalk or clay may be broken up and mixed. The slurry is then conveyed to the drying floors. When dried, it is broken up into pieces of suitable size, and put in the kilns mixed with alternate layers of coke. It is there calcined at a high temperature to the verge of vitrification. The resulting product, called “clinker,” is then ready for the reducing machinery, which has already been described in my hydraulic lime process.

In this country specifications for cement are numerous and varied. Engineers and architects do not agree upon any standard, and much has been said as to Government being asked to fix a standard, as is done in Germany and Austria and some other

countries; but our Government are not so paternal in their legislation.

#### TESTING.

The true and only reliable tests are mechanical ones—namely, strength, weight, and fineness. Experience has proved that the weight tests are of little value to the user, but are of value to the manufacturer in dealing with the same raw materials. The weight test is so far a guide to the degree of calcination—the higher the burning, the heavier will be the cement, taking into account the fineness. Fineness of grinding is coming to be more and more insisted on, but there is a point beyond which it would not be economical, owing to the extra cost of reducing the cement beyond a certain point; however, it is only the impalpable powder that has any cementing property, the residue on a sieve of almost any fineness having no cohesive or adhesive power whatever.

#### AIR-SLAKING, COOLING, AND MATURING PROCESS.

I come now to speak of a process patented by me some time ago for dealing with the free lime that is found to exist in all Portland cements.

In the papers read by Scott and Redgrave, and Grant, at a meeting of the Institution of Civil Engineers, to which I have already referred, and in the discussion thereon, which was taken part in by the most eminent scientific and practical authorities on the subject, there were developed differences of opinion in regard to various matters, but there was a remarkable consensus of opinion in regard to one point—namely, the imperative necessity of dealing with the free lime and rendering it innocuous by air-slaking, previous to allowing the use of the cement. Manufacturers and scientists alike are all agreed upon this. The former issue printed instructions cautioning their customers against the use of cement that has not been exposed sufficiently to the action of air to slake the particles of free lime. The latter insist upon the cement being so treated upon all important contracts. Mr. Bernays, Engineer to the Chatham Extension Works, speaking at the meeting referred to, said:—“He was so impressed with the danger of using Portland cement in a fresh state, that even when packed in casks and taking months to reach its destination, he considered it just as necessary

to turn it out of the casks and expose it to the free action of the air, as if it had come from the millstones but a few hours."

Henry Reid, C.E. (on "Concrete," &c., page 51), says:—"The result of engineering experience confirms the now unquestioned fact, that the value of Portland cement especially increases in proportion to its slowness of 'setting' and final induration."

Engineers and architects generally are giving more attention to the maturing of Portland cement, and in their specifications are imposing conditions requiring that the cement should be stored in bulk, and exposed for a longer or shorter period before it is allowed to be used on the works.

To prove the presence of free lime you have only to empty the contents of a sack on the floor, and after a few days exposure examine it closely. You will then find it fissured all over with seams and cracks, showing unmistakeably the disruptive effects of the free lime. It is therefore clear, and now invariably admitted, that Portland cement should be kept exposed to the air for a sufficient time to allow of the air-slaking of the particles of the free lime. We are all familiar with the mischief wrought by this objectionable ingredient, the result of using the cement too fresh. The free lime must slake at sometime or other, and the slaking is always accompanied by an increase in bulk, and consequent displacement of surrounding parts; so that the choice can only lie between whether we shall have this element slaked before using the cement, or allow it to slake of itself after the cement has been used and in position; that is to say, whether we shall have it slaked while it is safe to do so, or wait till it becomes a source of danger.

If further evidence were needed in proving the evil effects of free lime, it is given in the briquettes now exhibited in various stages of disintegration. These briquettes each represent a consignment of cement from the manufacturers, averaging from 80 to 200 tons and upwards, and nearly every London manufacturer of repute is represented amongst them.

After considerable study and numerous experiments, I was led to adopt a process whereby the desired object of rendering the free lime entirely innocuous is completely attained. I have fully described this process in a pamphlet issued some time ago, and shall now only briefly explain it.

The cement is first hoisted to an upper floor of the store, the

sacks emptied, and contents bulked, after which the cement is gradually fed into a receiver, from which it is made to fall down a cylinder or trunk, where, by a particular arrangement, it is caught at frequent intervals on a series of perforated shelves, constructed in a special manner, so as to thoroughly open up the body of the cement and delay its passage, while all the time a constant blast of cold air is directed upon every particle from a perforated pipe, through which a current of cold air is forced by a fan driven by steam-power. The cement is subjected to this aërating process during the whole time of its passage from the receiver until it falls on the floor, where it is allowed to lie for some time in this aërated condition to ensure the full effect of the process. The process of maturing is much facilitated by the addition of a small percentage of finely pulverised carbonate of lime, and a decided improvement effected thereby, the carbonate having a marked influence in the "setting" of free lime, which it is proved exists more or less in all Portland cements.

The ground carbonate contains always a certain amount of moisture in which a proportion of the carbonate and bicarbonate of lime exist in the soluble state. The extreme avidity of the free lime for water causes it immediately to absorb this moisture, and in doing so it slakes, thereby losing its power for evil, and not only so, but becoming to a slight extent hydraulic by the absorption of carbonic acid from the bicarbonate in solution. I am also inclined to think that when water is added in making up mortar or concrete a further absorption of carbonic acid occurs aided by the heat which to some extent accompanies the process of slaking. That some action of this sort occurs is perfectly certain, otherwise the addition of a percentage of carbonate of lime would weaken the cement exactly in the same way as so much sand added; but, after a long series of careful experiments on the cements of many manufacturers, I have found the very reverse to be the fact, and instead of any weakening there is a perceptible gain in strength. Having found these effects from the application of carbonate to Portland cement, I searched some of the recognised authorities on limes and cements, and found much to confirm me in the adoption of the process. Burnell (page 77) says:—"Broken limestone appears to add very much to the qualities of concrete betons and mortars. Very probably this may be attributed to the affinity between the molecules of the already formed carbonate of lime and that which is in process of formation. The new crystals may

group themselves more easily about bodies whose form is similar to the one they are themselves to assume, or possibly there may be a tendency in the chemical elements to arrive at a state of equilibrium, and the carbonate of lime may therefore be supposed to part with a certain portion of its carbonic acid."

Burnell also mentions a discovery by a Mr. Westmacott, which formed the subject of a patent (page 130, appendix F):—"With a view to augmenting the resistance of the rendering coats of plaster that are executed in lime, by the admixture of pounded limestone with that material. This is in fact nothing more than the application of the principle mentioned in the text (page 77) where the tendency of the lime to crystallise around a gangue of the same nature as itself is referred to, and the inference is drawn that the presentation of the crystallised form of carbonate of lime would be favourable to the solidification of the mass of concrete betons or mortars. It is to be observed that Mr. Westmacott mixes with the chalk lime that he employs considerable quantities of pounded chalk, or of some equally common description of stone that has a base of carbonate of lime, and thus he obtains a mixture that is capable of setting with greater rapidity."

Vicat (page 65) says:—"To obtain mortars or cements capable of acquiring great hardness in the open air, and to resist rain and heat, we must combine (amongst other things) the powders of hard calcareous minerals;" and at page 201 he shows experiments with calcareous and granitic sands which are in favour of the former.

Henry Reid, C.E., says, at page 55:—"When in a moist state lime would probably dissolve a portion of any calcareous aggregate."

Major-General Gillmore gives various experiments to show that underburnt stones possess superior hydraulicity and contain carbonic acid, and that overburnt stones, from which the carbonic acid is driven off, are less or more deprived of "setting" power.

Tomlinson ("Cyclopædia," page 301) says:—"A very intimate mixture of quicklime and carbonate of lime has feeble hydraulic properties; and limestone gently heated, so that a large proportion of it remains in the form of carbonate, slightly hydraulic. In the burning of rich limes imperfectly burned fragments are always found which have this character, and it appears to be due to the forma-

tion of a definite compound of carbonate of lime and hydrate of lime."

Portland cement is different from all other hydraulic limes and cements, in respect that the high temperature required in the kilns to effect the chemical combination of the lime with the silica and alumina drives off nearly, though not quite, all the carbonic acid gas, and any particles of lime remaining uncombined, as is always the case to some extent, have been deprived of all hydraulic or "setting" properties, and remain in the cement as so much quick-lime; whereas, in all natural cements and hydraulic limes, there is left, after calcination, carbonic acid to the extent of from 6 to 8 per cent. In the analysis of the famous hydraulic lime of Theil, in France, carbonic acid is present to the extent of about 8 per cent. I would further call attention to the fact, demonstrated by analysis, that when cement is laid out to air-slake by the method usually adopted on large contracts, it increases in weight by the absorption of carbonic acid and moisture in the proportion of two-thirds of the former to one of the latter. This is the same result as is effected by my process, with this difference, that by my system the cement is acted upon equally throughout, while by the usual method it is only the exposed surfaces that are properly purged of the free lime, unless where frequently turned over at great cost. Other authorities might be quoted, but perhaps enough have been given for our purpose, and they go far to show that my air-slaking process, with the addition of carbonate, is based on sound principles, and fitted to grapple with and overcome an acknowledged difficulty and danger in the use of Portland cement.

As showing the reliability of cement so treated, and its freedom from either expansion or contraction, I may mention having last year laid from my quarry at Barrhead a 4-inch cast-iron syphon pipe, 600 yards long, the jointing being done throughout with this matured cement, and by unskilled workmen. The syphon has been at work for several months, during which time there have been alternate frost and thaw, and not a single joint has given way. None are likely to do so now, as it is well known that Portland cement in contact with cast-iron becomes almost as hard as the iron itself.

In hot weather the cement made in exactly the same proportions, and burnt to just the same extent as at other times, will "set" so rapidly that it can scarcely be handled, and it is also very apt to crack. This arises presumably from the difficulty of getting rid

of the mechanical heat in the cement, and it is not generally known, or, if known, not sufficiently appreciated, that almost all cements when they arrive in the Clyde are in a condition so fresh and quick-setting that the test briquettes cannot be made till the small sample required for the purpose has been laid out thinly on a cold floor from one to three or four days. While this is the case with the sample, the bulk of the cement is, in many cases, hurried into immediate use and made into concrete or mortar.

In the latter state it is frequently allowed to lie for hours, then turned over, adding more water, perhaps repeatedly, before it is all used up. I ask any one having experience of Portland cement whether good results are likely to follow the use of this cement under such circumstances, and whether there is not an evident and clear necessity for some efficient method of cooling and maturing the cement before it is allowed to be used for general purposes.

#### CHEMISTRY OF LIMES AND CEMENTS.

In reference to the chemistry of hydraulic limes and cements, it has been the custom of some engineers to specify a standard of quality by chemical analysis, and to insist upon certain proportions of lime, silica, alumina, &c. ; but when it can be shown that it is quite common to find limes and cements of a like analysis, possessing no other features in common, so far as regards their value as cementing materials, it will at once be understood that a chemical test, without a mechanical one, is of little value. On the other hand, if you find the mechanical test satisfactory, and the lime or cement shows good binding power, you need not trouble much about the analysis—precisely on the same principle as a ship or bridge builder, on proving his iron or steel by mechanical test, will not concern himself much as to its chemical properties. An illustration of this came under my own observation a few years ago. I ventured to suggest to the engineer of one of our Scotch railways, who had been accustomed to specify by analysis, that he might make up briquettes and test the hydraulic lime on his Portland cement testing machine, when he told me he had done so on several occasions, but never found it give any practical results. I supplied him with samples both of lime and briquettes; his test of the latter showed even better results than I had obtained on my own machine, and he was also highly pleased with the lime, which

he said stood his test in a way that he never got Arden lime to stand before. The standard of analysis given by him, and one or two other engineers, is as follows:—

Lime, . . . .	45·64 per cent., or 43·00 per cent.	
Magnesia, . . .	1·37	1·72
Carbonic acid, . .	7·95	6·10
Phosphoric acid, . .	·09	·12
Sulphuric acid, . .	1·65	2·19
Water, . . . .	·48	·68
Oxide of iron, . .	2·92	2·64
Alumina, . . . .	6·69	6·64
Silica, . . . .	33·40	37·40
	<hr/> 100·19	<hr/> 100·47

The above was arrived at by analysing two samples (probably selected) about the time the Arden lime was first brought into the market; but when it can be shown that a material of precisely similar analysis could be supplied, having neither cohesive nor adhesive properties, it will at once be seen that a chemical test, without a mechanical one, is of little value. In illustration of this, I may mention a series of tests which were recently made on two different hydraulic limes supplied to a contract not a hundred miles distant. Samples of each were sent to an analytical chemist for analysis, and to another person experienced in the mechanical test. The results in seven days were as follow:—

Lime, 87 per cent. Tensile strength: out of water, 100 lbs.; in water, 47 lbs.  
 " 40 " " " 70 " " 0 "

It will be seen that no greater mistake could be made than to insist upon the maximum of lime, and it should be kept in mind that the hydraulic or "setting" properties are due to the presence of silica, alumina, magnesia, and carbonic acid, and that common limes, while richer in lime, are devoid of hydraulic or self-setting energy.

The same remarks apply to Portland cement, and it has been demonstrated that the analysis may be correct in every respect, and yet the material may be quite inert, having neither cohesive nor adhesive properties.

In some recent articles appearing in *Industries*, the writer says:—"Passing from the critical to the constructive attitude, we may first discuss the question of defining what is meant by Portland cement. There exist two ways in which this may be done—(1) by making the definition rest on the composition

(2) by referring it to the raw materials and mode of manufacture. Taking the first of these, a definition would run something like this:—'Portland cement consists of a mixture of tricalcium silicate and tricalcium aluminate, in which the former preponderates, together with small quantities of calcium-silico-aluminate and ferrite. In ultimate composition it varies between the following limits:—Lime, 55 to 65 per cent.; silica, 19 to 23 per cent.; alumina, 5 to 10 per cent.; ferric oxide, 3 to 5 per cent.' Such a definition as this has many faults. It is clumsy, but that might be forgiven; its limits are wide, and yet might prove scarcely wide enough in some cases. It will be seen that in spite of this it is vastly more accurate than one prescribing merely the percentages of the oxides which occur in ordinary samples could be, because it requires that those oxides shall be defined in a certain definite manner; otherwise there is nothing to prevent a mere mixture of lime, alumina, silica, and ferric oxide in suitable proportions from passing the test, although destitute of the properties of cement."

Manufacturers will be slow to admit these wide variations, and in my experience they do not exceed 57 to 62 per cent., except in very rare instances. Scott and Redgrave, in their joint paper read before the Institution of Civil Engineers, and already referred to, say:—"It is useless to conceal the fact that the exact percentage of clay which is added to the lime is far less accurately determined than most manufacturers are willing to admit; and within certain *not very clearly defined limits*, all mixtures which contain, say, 74 and 77 per cent. of carbonate of lime, when sufficiently calcined, will yield a good sample of Portland cement."

#### EFFECT OF MAGNESIA.

There is one other point to which I think it necessary to refer before going into the comparative costs—namely, the question of *magnesia* in hydraulic limes. Any objection to this ingredient which I have seen is of comparatively recent date; the most recent is in the series of articles in *Industries*, and already referred to, the last of which is in the number of 16th October, 1891. The writer says:—"Although an unreasoning scare, based, moreover, on a complete misapprehension, arose some time ago concerning *magnesia* in cement, and is only now subsiding, yet it is fairly certain that cements in which a considerable amount of *magnesia* is present are less reliable than those of

normal quality. Whether this unreliability be inherent or adventitious, cannot be considered here; the fact remains, and in the present state of our knowledge a limit of three per cent. of magnesia may be fairly adopted. Such a limit would be found a hardship by no one, nearly all English cement of good quality complying with it easily." You will observe that while the writer speaks of the objection to magnesia, as an unreasoning scare, based on a complete misapprehension, yet he proceeds to fix a limit to the quantity at three per cent., apparently on no other grounds than that it would be no hardship to the manufacturer to have the limit fixed at that amount; and neither it would, as his raw materials do not contain more, at least on the Thames and Medway.

The writer does not give any indication of the origin of the unreasoning scare alluded to, or give any particulars on which to form an opinion. Probably it was some instance in which damage occurred through the action of sea water containing magnesia; but it has never been shown that any defect could be traced to the presence of magnesia in the cement. On the contrary, it is well established that magnesia plays an important part in the "setting" of hydraulic limes and cements, and many authorities might be cited in proof of this. Vicat, after many experiments, was led to recommend magnesia as a suitable ingredient of mortars to be immersed in the sea, stating that if it could be obtained at a cost that would admit its application to such purposes, the problem of making concrete unalterable by sea-water would be solved.

General Gillmore, speaking of the American lime and cement deposits, says:—"Magnesia plays an important part in the "setting" of mortars, derived from the argillo-magnesian limestones, such as those which furnish the Rosendale cements. The magnesia, like the lime, appears in the form of a carbonate. During calcination, the carbonic acid is driven off, leaving protoxide of magnesia, which comports itself like lime in the presence of silica and alumina, by forming silicate of magnesia and aluminate of magnesia. These compounds become hydrated in the presence of water, and are pronounced by both Vicat and Chatoney to furnish gangues, which resist the dissolving action of sea-water better than the silicate and aluminate of lime. This statement is doubtless correct, for we know that all of these compounds, whether in air or water, absorb carbonic acid, and

pass to the condition of subcarbonates, and that the carbonate of lime is more soluble in water holding carbonic acid, and certain organic acids of the soil in solution, than the carbonate of magnesia. At all events, whatever may be the cause of the superiority, it is pretty well established by experience that the cements derived from the argillo-magnesian limestones furnish a durable cement for constructions in the sea." In Marshal Vaillant's report to the French Academy of Sciences, from the Commission to which Chatoney and Rivoir's paper was referred in 1856, this superiority of the magnesian hydrates is distinctly asserted. A few years ago the French Government Office of Civil Engineers made a series of comparative tests on three samples each of French, English, and German cement, in which the results are given in favour of the German cement, which contained magnesia to the extent of 2.4 per cent., against 0.26 in the English and 0.32 in the French, and summed up thus:—"A great value is to be placed on the presence of magnesia, and the excellence of the German cement is partly due to the higher percentage of magnesia contained in it." Gillmore further says that magnesian limestone furnishes nearly all the hydraulic cement manufactured in the western part of the State of New York. At East Vienna it has been used for cement, and at Akron, Erie Co., N.Y., a manufactory of some extent is in operation.

Captain Smith (translator of Vicat) says:—"Having analysed several old mortars, with the view of discovering, if possible, to what their superior durability might be attributed, I found, in some excellent specimens of very old mortar, magnesia to exist in considerable proportion." The limestones, therefore, from which these mortars were prepared must have contained the silica and magnesia as constituent ingredients; and it is to be remembered, that it is the presence of these substances which communicates the property of hardening under water.

Professor Scorgie, in his work already referred to, says of carbonate of magnesia:—"Magnesium carbonate is a substance very similar to carbonate of lime; it loses its carbonic acid in burning, combines with silica, &c., and behaves generally in the same way; it does not slake, however, on being wetted, but combines with the water gradually, and quietly sets to some extent in doing so. Magnesium carbonate, combined with lime, reduces the energy of the slaking, and increases that of the "setting" processes; when other substances are present, its behaviour

and combination with them are similar to those of lime. When carbonate of magnesia is present in sufficient quantity,—say, about 30 per cent.—it renders lime hydraulic independently of and in the absence of clay.” Colonel Pasley also, by experiments, demonstrated that magnesian limestones are suitable for hydraulic mortars.

As shown, when dealing with the common limes, the Campsie lime, and others of the same strata, have a reputation which seems to be largely due to the presence of magnesia. The Campsie lime also, in its slaking action, justifies Professor Scorgie’s assertion that magnesium carbonate, combined with lime, reduces the energy of the slaking, and increases that of the “setting” processes. Many such evidences showing the value of magnesia in hydraulic mortars might be quoted, but perhaps these are sufficient.

#### ON THE USE OF SAND IN MORTARS.

Regarding the use of sand in mortars, it may almost be spoken of as a necessary evil. In the common rich limes we have seen that pozzuolana and not sand should be used, but if the former cannot be had conveniently, then sand, though not properly a substitute, is necessary to give body to an otherwise too soft and plastic material, and the coarser and cleaner the better, as the coarse particles allow the carbonic acid to penetrate further into the body of the mortar, and assist in the hardening process for this reason. In the case of cements of all kinds sand is only good for lessening the cost of the aggregate, and in the case of the majority of sands in daily use here, the strength is reduced out of all proportion to the saving effected. Brunel, in making the Thames Tunnel, was so convinced of this that he used pure Portland cement in the arches; and General Pasley, treating of this, recommends that only pure cement should be used on all arduous works.

As to the quality of sands, they are of very wide variety, so much so, that one part of an inferior or soft clayey sand will reduce the strength of mortar as much as three or four parts of clean sharp granitic sand. This is well exemplified in the sand test, which is made with what is called standard sand, being a pure silicious sand sifted through a sieve of 400 holes to the square inch and retained on one of 900. The three parts of sand and one of cement being then carefully mixed in a dry state, sufficient water is added to damp or moisten the whole—not made into a plastic mortar as in practice. It is then again well turned

over, scarcely having the appearance of moisture, and afterwards beaten into the moulds. These briquettes will in 28 days meet the required tensile strain standard of 175 lbs. to the square inch. But what relation do they bear to the mortar of 3 to 1 in ordinary practice? We shall see further on.

#### RELATIVE COST OF HYDRAULIC MORTARS.

I should like now to give some figures as to the comparative cost of hydraulic mortars, but fear I may have already exceeded the time which the interest in my paper would warrant.

I have, however, arranged these as briefly as practicable. The relative cost of Portland cement and Arden hydraulic lime per ton may be fairly taken as 36s. and 12s., respectively, and the weight per bushel as 112 lbs. and 75 lbs. Mortars are all made by measure, and thus while a ton of 2,240 lbs. Portland cement costs 36s., an equal bulk of hydraulic lime weighs only 1,500 lbs. and costs 8s.; thus Portland cement may be put at  $4\frac{1}{2}$  times the cost of hydraulic lime, bulk for bulk.

In using cement and common sand for mortar, no general standard of strength can be always attained, as the qualities of the sands in use vary so much. From a series of tests made with ordinary Clyde sand, I was unable to obtain a higher average tensile strength at 28 days than 61 lbs. per square inch, using cement tested by itself at 400 lbs. in 7 days, equal to at least 450 in 28 days, and sand in the proportion of 1 to 3. This result is only about one-third of what the test should have been with standard sand, but we know that the latter is not used in actual practice. After the lapse of the same period, I have found Arden hydraulic lime briquettes to stand a tensile strain of 150 to 200 lbs. per square inch. Taking, therefore, the cost of 1 ton Portland cement at 36s., 3 tons sand at 3s. per ton, and the cost of mixing and making up the mortar at, say, 5s., we find the total cost of the aggregate of 4 tons to be 50s., equal to 12s. 6d. per ton of a mortar capable of resisting 61 lbs.; while for 8s. we get an equal bulk of Arden lime, capable of resisting 150 lbs. tensile strain per square inch.

At this rate the addition of only  $1\frac{1}{2}$  parts common sand to every part of cement would reduce the tensile resistance of the mortar to an equality with that of Arden hydraulic lime; but, instead of the aggregate costing 12s. 6d. per ton, it would cost nearer 20s. per ton, against 8s. for the Arden hydraulic lime.

Again, if we take 12s. 6d. as the cost of a ton of Portland cement mortar, 1 part cement to 3 parts common sand, the proportionate value of an equal bulk of Arden hydraulic lime should be 30s. 9d. per ton. If, on the other hand, we reverse the order, and take Arden hydraulic lime as the standard, a quantity equal in bulk to a ton of Portland cement costs 8s. ; while a ton of Portland cement mortar made with common sand, and only capable of resisting 61 lbs. as against 150 lbs., is only value for 3s. 3d. per ton—thus showing unmistakably the great loss in value of the cement as a mortar when used with common sand, and showing such a mortar to be worth little more than one-third the value of Arden hydraulic lime used by itself.

The tests referred to were made up in small quantities capable of being manipulated by the trowel. The cement and sand were much more carefully measured and mixed than they can be in actual practice, and the mortar thoroughly wrought up to bring out the highest possible results.

As an illustration of the actual practice, I have here some briquettes of Portland cement mortar got from a large contract in the town twelve months ago. These briquettes were tested on my machine after 28 days, but failed to move it, and broke without indicating any degree of tensile strength. The briquettes remaining are now twelve months old, and have gained apparently very little strength in the interval.

In case these figures and comparisons should seem to convey the impression that I put forward this hydraulic lime as a substitute to be preferred generally to Portland cement, it is perhaps necessary to say that I disclaim any such intention, and to explain that what is claimed for it, and can be well demonstrated, is that in all cases where cement-mortar is used, and in buildings not immediately in contact with water, such as the walls and arches in underground city railways and similar works, it would be true economy in every sense to exhaust the possibilities of this hydraulic lime with and without sand before using Portland cement and sand.

Gillmore, at page 503, says:—"M. Pascal, an eminent French engineer, who had large experience at Marseilles harbour and elsewhere, expressed his preference for good hydraulic lime over any pozzuolana mixture, or any natural or artificial cements, provided plenty of time could be allowed to harden before immersion."

M. Vicat also intimates that the Theil hydraulic lime is the

only one with which he is acquainted that could unquestionably furnish a mortar indestructible by sea-water.

Many fine structures have been erected in Europe of concrete made of Theil lime. Of the Vanne aqueduct for supplying water to Paris, 37 miles have been executed in this concrete. In the Forest of Fontainebleau there are about three miles of arches, some of which are 50 feet high. The whole structure, including arches and pipe, is one mass of solid masonry without joints. A Gothic church at Vezinet, near Paris, having a spire of 130 feet high, is also a monolith of concrete of lime of Theil. The lighthouse at Port Said, the northern terminus of the Suez Canal, is also built of concrete of Theil lime and Port Said sand, and is a monolith 180 feet high. The jetties which form the harbour of Port Said are built of huge blocks of concrete formed of the same material. In their construction, 120,000 tons of Theil hydraulic lime were used. There were 25,000 blocks each weighing 25 tons. The docks of Marseilles were constructed of similar concrete. At the harbour of Algiers, commencing in 1833, the French constructed blocks of hydraulic lime concrete, containing 353 cubic feet each to withstand the force of the sea. The blocks weigh about 25 tons each. The harbour works of Alexandria, Egypt, consumed 175,000 tons of Theil lime in the construction of concrete blocks similar to those of Port Said.

There can be no doubt that a cement of slow-setting properties, such as this hydraulic lime, is safer to work with, especially where it does not come immediately into contact with water; and Professor Scorgie, in his treatise already alluded to, says—"Hydraulic limes are of much use for all the ordinary conditions of building; as, on the one hand, where the building is not likely to be exposed immediately to the action of water, and where its action is not severe; or where, on the other hand, it would be improper to use pure limes, as explained before. In the use of hydraulic limes, moreover, there is less danger than in the use of cements of an unskilled person spoiling the work."

#### CONCLUSION.

In regard to the suitability of our Scotch limes and cements for mortars in building construction, there is a large field for some scientific investigation, as in all the works I have seen on limes and cements Scotland and Scotsmen are conspicuous by their absence; England, France, Germany, Austria, America, &c.,

are well represented; and it is to be remarked that those who have investigated the subject are principally military officers. This is not to be wondered at, seeing that the subject is one which requires a great amount of time and exceptional facilities for the work.

The varieties of limestones to be examined are so many, and the time required for them to develop their special qualities is in many cases so long, that a thorough and exhaustive inquiry into the subject would be a work of years.

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III.—*How our Bones Grow*. By JOHN CLELAND, M.D., D.Sc.,  
F.R.S., Professor of Anatomy in the University of Glasgow.

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[Read before the Society, 2nd December, 1891.]

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(PLATE I.)

GROWTH is a word which includes both increase of bulk and evolution of form. But we do not know in the least what the forces are which lead to the bones or any other part of the body developing the forms which they ultimately assume. I leave that question alone. The growth I have to deal with is not the building of the cathedral, but the manufacture of the bricks of which the cathedral is built. I enquire into the method by which bone increases in bulk, not the agents at work to shape it, so as to take its part in the organism. Now, to understand the growth of bone properly one must begin at the beginning, and recognise that every complex organism, whether vegetable or animal, consists really of a vast colony of minute beings. We are made up of a multitude of microscopic structures which we are in the habit of speaking of as nucleated corpuscles or cells. "Nucleated cells" is, perhaps, the most frequent term. For my own part, I prefer the term "corpuscles," because the essential part is not a hollow cell or vesicle, but a mass of protoplasm. These minute masses of protoplasm are living bodies, which in their simplest form are of rounded figure, sometimes throwing out branches in different directions, while in their interior there is a firmer body called a nucleus.

Much more might be said with regard to the composition of such corpuscles, but it is sufficient for you to know that the textures of our bodies all grow through their instrumentality. They all consist either of simple corpuscles, such as I have represented on the slate, or of more complex elements derived from such simple corpuscles, to which in many instances there is added substance deposited between, which is called the stroma or matrix. But even the matrix is deposited under the influence of the corpuscles, for each of these has power to draw material from without into its interior, to assimilate it or

he said stood his test in a way that he never got Arden lime to stand before. The standard of analysis given by him, and one or two other engineers, is as follows:—

Lime, . . . .	45·64	per cent., or 43·00	per cent.
Magnesia, . . . .	1·37	„ „	1·72 „
Carbonic acid, . . . .	7·95	„ „	6·10 „
Phosphoric acid, . . . .	·09	„ „	·12 „
Sulphuric acid, . . . .	1·65	„ „	2·19 „
Water, . . . .	·48	„ „	·66 „
Oxide of iron, . . . .	2·92	„ „	2·64 „
Alumina, . . . .	6·69	„ „	6·64 „
Silica, . . . .	33·40	„ „	37·40 „
	<hr/>		
	100·19		100·47

The above was arrived at by analysing two samples (probably selected) about the time the Arden lime was first brought into the market; but when it can be shown that a material of precisely similar analysis could be supplied, having neither cohesive nor adhesive properties, it will at once be seen that a chemical test, without a mechanical one, is of little value. In illustration of this, I may mention a series of tests which were recently made on two different hydraulic limes supplied to a contract not a hundred miles distant. Samples of each were sent to an analytical chemist for analysis, and to another person experienced in the mechanical test. The results in seven days were as follow:—

Lime, 37 per cent. Tensile strength: out of water, 100 lbs.; in water, 47 lbs.

„ 49 „ „ „ 70 „ „ 0 „

It will be seen that no greater mistake could be made than to insist upon the maximum of lime, and it should be kept in mind that the hydraulic or “setting” properties are due to the presence of silica, alumina, magnesia, and carbonic acid, and that common limes, while richer in lime, are devoid of hydraulic or self-setting energy.

The same remarks apply to Portland cement, and it has been demonstrated that the analysis may be correct in every respect, and yet the material may be quite inert, having neither cohesive nor adhesive properties.

In some recent articles appearing in *Industries*, the writer says:—“Passing from the critical to the constructive attitude, we may first discuss the question of defining what is meant by Portland cement. There exist two ways in which this may be done—(1) by making the definition rest on the composition;

(2) by referring it to the raw materials and mode of manufacture. Taking the first of these, a definition would run something like this:—'Portland cement consists of a mixture of tricalcium silicate and tricalcium aluminate, in which the former preponderates, together with small quantities of calcium-silico-aluminate and ferrite. In ultimate composition it varies between the following limits:—Lime, 55 to 65 per cent.; silica, 19 to 23 per cent.; alumina, 5 to 10 per cent.; ferric oxide, 3 to 5 per cent.' Such a definition as this has many faults. It is clumsy, but that might be forgiven; its limits are wide, and yet might prove scarcely wide enough in some cases. It will be seen that in spite of this it is vastly more accurate than one prescribing merely the percentages of the oxides which occur in ordinary samples could be, because it requires that those oxides shall be defined in a certain definite manner; otherwise there is nothing to prevent a mere mixture of lime, alumina, silica, and ferric oxide in suitable proportions from passing the test, although destitute of the properties of cement."

Manufacturers will be slow to admit these wide variations, and in my experience they do not exceed 57 to 62 per cent., except in very rare instances. Scott and Redgrave, in their joint paper read before the Institution of Civil Engineers, and already referred to, say:—"It is useless to conceal the fact that the exact percentage of clay which is added to the lime is far less accurately determined than most manufacturers are willing to admit; and within certain *not very clearly defined limits*, all mixtures which contain, say, 74 and 77 per cent. of carbonate of lime, when sufficiently calcined, will yield a good sample of Portland cement."

#### EFFECT OF MAGNESIA.

There is one other point to which I think it necessary to refer before going into the comparative costs—namely, the question of magnesia in hydraulic limes. Any objection to this ingredient which I have seen is of comparatively recent date; the most recent is in the series of articles in *Industries*, and already referred to, the last of which is in the number of 16th October, 1891. The writer says:—"Although an unreasoning scare, based, moreover, on a complete misapprehension, arose some time ago concerning magnesia in cement, and is only now subsiding, yet it is fairly certain that cements in which a considerable amount of magnesia is present are less reliable than those of

normal quality. Whether this unreliability be inherent or adventitious, cannot be considered here; the fact remains, and in the present state of our knowledge a limit of three per cent. of magnesia may be fairly adopted. Such a limit would be found a hardship by no one, nearly all English cement of good quality complying with it easily." You will observe that while the writer speaks of the objection to magnesia, as an unreasoning scare, based on a complete misapprehension, yet he proceeds to fix a limit to the quantity at three per cent., apparently on no other grounds than that it would be no hardship to the manufacturer to have the limit fixed at that amount; and neither it would, as his raw materials do not contain more, at least on the Thames and Medway.

The writer does not give any indication of the origin of the unreasoning scare alluded to, or give any particulars on which to form an opinion. Probably it was some instance in which damage occurred through the action of sea water containing magnesia; but it has never been shown that any defect could be traced to the presence of magnesia in the cement. On the contrary, it is well established that magnesia plays an important part in the "setting" of hydraulic limes and cements, and many authorities might be cited in proof of this. Vicat, after many experiments, was led to recommend magnesia as a suitable ingredient of mortars to be immersed in the sea, stating that if it could be obtained at a cost that would admit its application to such purposes, the problem of making concrete unalterable by sea-water would be solved.

General Gillmore, speaking of the American lime and cement deposits, says:—"Magnesia plays an important part in the "setting" of mortars, derived from the argillo-magnesian limestones, such as those which furnish the Rosendale cements. The magnesia, like the lime, appears in the form of a carbonate. During calcination, the carbonic acid is driven off, leaving protoxide of magnesia, which comports itself like lime in the presence of silica and alumina, by forming silicate of magnesia and aluminate of magnesia. These compounds become hydrated in the presence of water, and are pronounced by both Vicat and Chatoney to furnish gangues, which resist the dissolving action of sea-water better than the silicate and aluminate of lime. This statement is doubtless correct, for we know that all of these compounds, whether in air or water, absorb carbonic acid, and

pass to the condition of subcarbonates, and that the carbonate of lime is more soluble in water holding carbonic acid, and certain organic acids of the soil in solution, than the carbonate of magnesia. At all events, whatever may be the cause of the superiority, it is pretty well established by experience that the cements derived from the argillo-magnesian limestones furnish a durable cement for constructions in the sea." In Marshal Vaillant's report to the French Academy of Sciences, from the Commission to which Chatoney and Rivot's paper was referred in 1856, this superiority of the magnesian hydrates is distinctly asserted. A few years ago the French Government Office of Civil Engineers made a series of comparative tests on three samples each of French, English, and German cement, in which the results are given in favour of the German cement, which contained magnesia to the extent of 2.4 per cent., against 0.26 in the English and 0.32 in the French, and summed up thus:—"A great value is to be placed on the presence of magnesia, and the excellence of the German cement is partly due to the higher percentage of magnesia contained in it." Gillmore further says that magnesian limestone furnishes nearly all the hydraulic cement manufactured in the western part of the State of New York. At East Vienna it has been used for cement, and at Akron, Erie Co., N.Y., a manufactory of some extent is in operation.

Captain Smith (translator of Vicat) says:—"Having analysed several old mortars, with the view of discovering, if possible, to what their superior durability might be attributed, I found, in some excellent specimens of very old mortar, magnesia to exist in considerable proportion." The limestones, therefore, from which these mortars were prepared must have contained the silica and magnesia as constituent ingredients; and it is to be remembered, that it is the presence of these substances which communicates the property of hardening under water.

Professor Scorgie, in his work already referred to, says of carbonate of magnesia:—"Magnesium carbonate is a substance very similar to carbonate of lime; it loses its carbonic acid in burning, combines with silica, &c., and behaves generally in the same way; it does not slake, however, on being wetted, but combines with the water gradually, and quietly sets to some extent in doing so. Magnesium carbonate, combined with lime, reduces the energy of the slaking, and increases that of the "setting" processes; when other substances are present, its behaviour

and combination with them are similar to those of lime. When carbonate of magnesia is present in sufficient quantity,—say, about 30 per cent.—it renders lime hydraulic independently of and in the absence of clay.” Colonel Pasley also, by experiments, demonstrated that magnesian limestones are suitable for hydraulic mortars.

As shown, when dealing with the common limes, the Campsie lime, and others of the same strata, have a reputation which seems to be largely due to the presence of magnesia. The Campsie lime also, in its slaking action, justifies Professor Scorgie’s assertion that magnesium carbonate, combined with lime, reduces the energy of the slaking, and increases that of the “setting” processes. Many such evidences showing the value of magnesia in hydraulic mortars might be quoted, but perhaps these are sufficient.

#### ON THE USE OF SAND IN MORTARS.

Regarding the use of sand in mortars, it may almost be spoken of as a necessary evil. In the common rich limes we have seen that pozzuolana and not sand should be used, but if the former cannot be had conveniently, then sand, though not properly a substitute, is necessary to give body to an otherwise too soft and plastic material, and the coarser and cleaner the better, as the coarse particles allow the carbonic acid to penetrate further into the body of the mortar, and assist in the hardening process for this reason. In the case of cements of all kinds sand is only good for lessening the cost of the aggregate, and in the case of the majority of sands in daily use here, the strength is reduced out of all proportion to the saving effected. Brunel, in making the Thames Tunnel, was so convinced of this that he used pure Portland cement in the arches; and General Pasley, treating of this, recommends that only pure cement should be used on all arduous works.

As to the quality of sands, they are of very wide variety, so much so, that one part of an inferior or soft clayey sand will reduce the strength of mortar as much as three or four parts of clean sharp granitic sand. This is well exemplified in the sand test, which is made with what is called standard sand, being a pure silicious sand sifted through a sieve of 400 holes to the square inch and retained on one of 900. The three parts of sand and one of cement being then carefully mixed in a dry state, sufficient water is added to damp or moisten the whole—not made into a plastic mortar as in practice. It is then again well turned

over, scarcely having the appearance of moisture, and afterwards beaten into the moulds. These briquettes will in 28 days meet the required tensile strain standard of 175 lbs. to the square inch. But what relation do they bear to the mortar of 3 to 1 in ordinary practice? We shall see further on.

#### RELATIVE COST OF HYDRAULIC MORTARS.

I should like now to give some figures as to the comparative cost of hydraulic mortars, but fear I may have already exceeded the time which the interest in my paper would warrant.

I have, however, arranged these as briefly as practicable. The relative cost of Portland cement and Arden hydraulic lime per ton may be fairly taken as 36s. and 12s., respectively, and the weight per bushel as 112 lbs. and 75 lbs. Mortars are all made by measure, and thus while a ton of 2,240 lbs. Portland cement costs 36s., an equal bulk of hydraulic lime weighs only 1,500 lbs. and costs 8s.; thus Portland cement may be put at  $4\frac{1}{2}$  times the cost of hydraulic lime, bulk for bulk.

In using cement and common sand for mortar, no general standard of strength can be always attained, as the qualities of the sands in use vary so much. From a series of tests made with ordinary Clyde sand, I was unable to obtain a higher average tensile strength at 28 days than 61 lbs. per square inch, using cement tested by itself at 400 lbs. in 7 days, equal to at least 450 in 28 days, and sand in the proportion of 1 to 3. This result is only about one-third of what the test should have been with standard sand, but we know that the latter is not used in actual practice. After the lapse of the same period, I have found Arden hydraulic lime briquettes to stand a tensile strain of 150 to 200 lbs. per square inch. Taking, therefore, the cost of 1 ton Portland cement at 36s., 3 tons sand at 3s. per ton, and the cost of mixing and making up the mortar at, say, 5s., we find the total cost of the aggregate of 4 tons to be 50s., equal to 12s. 6d. per ton of a mortar capable of resisting 61 lbs.; while for 8s. we get an equal bulk of Arden lime, capable of resisting 150 lbs. tensile strain per square inch.

At this rate the addition of only  $1\frac{1}{2}$  parts common sand to every part of cement would reduce the tensile resistance of the mortar to an equality with that of Arden hydraulic lime; but, instead of the aggregate costing 12s. 6d. per ton, it would cost nearer 20s. per ton, against 8s. for the Arden hydraulic lime.

Again, if we take 12s. 6d. as the cost of a ton of Portland cement mortar, 1 part cement to 3 parts common sand, the proportionate value of an equal bulk of Arden hydraulic lime should be 30s. 9d. per ton. If, on the other hand, we reverse the order, and take Arden hydraulic lime as the standard, a quantity equal in bulk to a ton of Portland cement costs 8s. ; while a ton of Portland cement mortar made with common sand, and only capable of resisting 61 lbs. as against 150 lbs., is only value for 3s. 3d. per ton—thus showing unmistakably the great loss in value of the cement as a mortar when used with common sand, and showing such a mortar to be worth little more than one-third the value of Arden hydraulic lime used by itself.

The tests referred to were made up in small quantities capable of being manipulated by the trowel. The cement and sand were much more carefully measured and mixed than they can be in actual practice, and the mortar thoroughly wrought up to bring out the highest possible results.

As an illustration of the actual practice, I have here some briquettes of Portland cement mortar got from a large contract in the town twelve months ago. These briquettes were tested on my machine after 28 days, but failed to move it, and broke without indicating any degree of tensile strength. The briquettes remaining are now twelve months old, and have gained apparently very little strength in the interval.

In case these figures and comparisons should seem to convey the impression that I put forward this hydraulic lime as a substitute to be preferred generally to Portland cement, it is perhaps necessary to say that I disclaim any such intention, and to explain that what is claimed for it, and can be well demonstrated, is that in all cases where cement-mortar is used, and in buildings not immediately in contact with water, such as the walls and arches in underground city railways and similar works, it would be true economy in every sense to exhaust the possibilities of this hydraulic lime with and without sand before using Portland cement and sand.

Gillmore, at page 503, says:—"M. Pascal, an eminent French engineer, who had large experience at Marseilles harbour and elsewhere, expressed his preference for good hydraulic lime over any pozzuolana mixture, or any natural or artificial cements, provided plenty of time could be allowed to harden before immersion."

M. Vicat also intimates that the Theil hydraulic lime is the

only one with which he is acquainted that could unquestionably furnish a mortar indestructible by sea-water.

Many fine structures have been erected in Europe of concrete made of Theil lime. Of the Vanne aqueduct for supplying water to Paris, 37 miles have been executed in this concrete. In the Forest of Fontainebleau there are about three miles of arches, some of which are 50 feet high. The whole structure, including arches and pipe, is one mass of solid masonry without joints. A Gothic church at Vezinet, near Paris, having a spire of 130 feet high, is also a monolith of concrete of lime of Theil. The lighthouse at Port Said, the northern terminus of the Suez Canal, is also built of concrete of Theil lime and Port Said sand, and is a monolith 180 feet high. The jetties which form the harbour of Port Said are built of huge blocks of concrete formed of the same material. In their construction, 120,000 tons of Theil hydraulic lime were used. There were 25,000 blocks each weighing 25 tons. The docks of Marseilles were constructed of similar concrete. At the harbour of Algiers, commencing in 1833, the French constructed blocks of hydraulic lime concrete, containing 353 cubic feet each to withstand the force of the sea. The blocks weigh about 25 tons each. The harbour works of Alexandria, Egypt, consumed 175,000 tons of Theil lime in the construction of concrete blocks similar to those of Port Said.

There can be no doubt that a cement of slow-setting properties, such as this hydraulic lime, is safer to work with, especially where it does not come immediately into contact with water; and Professor Scorgie, in his treatise already alluded to, says—"Hydraulic limes are of much use for all the ordinary conditions of building; as, on the one hand, where the building is not likely to be exposed immediately to the action of water, and where its action is not severe; or where, on the other hand, it would be improper to use pure limes, as explained before. In the use of hydraulic limes, moreover, there is less danger than in the use of cements of an unskilled person spoiling the work."

#### CONCLUSION.

In regard to the suitability of our Scotch limes and cements for mortars in building construction, there is a large field for some scientific investigation, as in all the works I have seen on limes and cements Scotland and Scotsmen are conspicuous by their absence; England, France, Germany, Austria, America, &c.,

are well represented; and it is to be remarked that those who have investigated the subject are principally military officers. This is not to be wondered at, seeing that the subject is one which requires a great amount of time and exceptional facilities for the work.

The varieties of limestones to be examined are so many, and the time required for them to develop their special qualities is in many cases so long, that a thorough and exhaustive inquiry into the subject would be a work of years.

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(PLATE I.)

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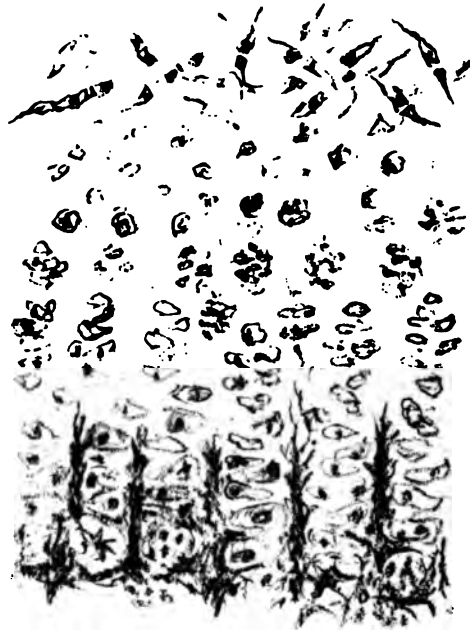
Much more might be said with regard to the composition of such corpuscles, but it is sufficient for you to know that the textures of our bodies all grow through their instrumentality. They all consist either of simple corpuscles, such as I have represented on the slate, or of more complex elements derived from such simple corpuscles, to which in many instances there is added substance deposited between, which is called the stroma or matrix. But even the matrix is deposited under the influence of the corpuscles, for each of these has power to draw material from without into its interior, to assimilate it or

make it like itself (that is to say, convert it into its own substance, and to cast off from its constitution the substances for which it has no further use); while many of them manufacture substances different from their own composition, and extrude them as soon as formed. Further, it is now universally allowed that all the nucleated corpuscles of our body are derived from pre-existing corpuscles. They have parentage and heredity just as much as separate organisms have. I need hardly say that single nucleated corpuscles of many forms occur as separate organisms. Indeed, we are so fond of illustrating the corpuscles of the tissues by reference to a particular set of small animals of the genus *amœba*, which throw out branches in different directions, and move about by means of those temporary limbs or *pseudopods*, that a corpuscle with similar powers of movement is often called an *amœboid* corpuscle. Not only so, but every living being, even the highest animal organism, in its earliest stage of existence, consists of a single corpuscle, which afterwards divides, so that, what was one corpuscle ultimately becomes two, and, by each of these dividing again in the same way, becomes the first parent of all the future corpuscles of the body. By such processes of multiplication of corpuscles all the textures are formed, and bone is no exception to the rule. Bone is one of the many textures which consist of corpuscle and matrix. There is a large group of tissues so constituted, often joined together under the name of connective or binding tissues. Typical connective tissue is that white substance which, for instance, in a raw beef-steak you can see joining together the fleshy parts or muscular fibres. It is called by various names in different circumstances according as it forms tendons, ligaments, or coverings of different densities; and bone is a specially modified form of this class of tissue, while gristle is another.

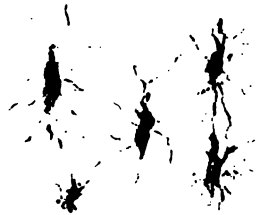
You will understand at once that the special peculiarity of bone which presents a difficulty to be got over in the way of nourishment and growth lies in the fact that it is so hard—very much harder than any of the other tissues. The difficulty may be well illustrated by reference to that texture from which the greater number of the bones in our body are formed—viz., cartilage, or more familiarly, gristle. You know that what afterwards constitutes a single bone is often, in the young animal, composed of separate parts. You may observe this in lamb for the table, or in so-called mutton: for you are aware that mutton is most frequently derived from anything but an adult specimen of the species. But



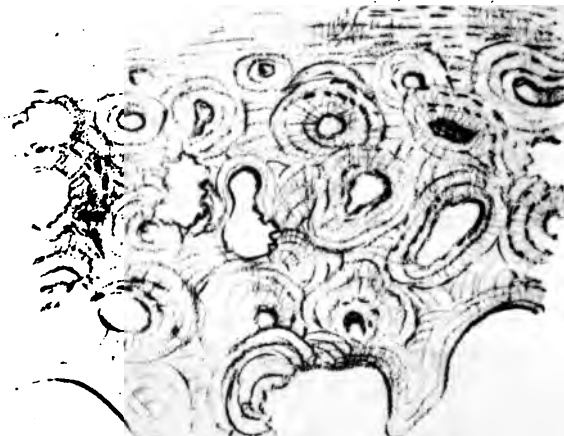
MICROSCOPIC STRUCTURE OF BONE,  
Illustrating Prof. Cleland's Paper.



1.



3.



if you carry your observations further, and look at much younger bones, you will find you have large blocks of cartilage to deal with, and will often see bony tissue making its appearance in the heart of such blocks. Examined under the microscope, cartilage is seen to be made up of incapsuled corpuscles scattered through a stiff matrix. Thus, in this diagram, some little distance from the ossifying edge in the shaft of a young bone, still in great part cartilaginous, you will find the corpuscles scattered broadcast. But it happens that cartilage always grows more rapidly immediately previous to being converted into bone, as may be judged from the totally different arrangements of corpuscles met with as we approach the ossifying edge. There is a reason for this. Cartilage has no bloodvessels. There is nothing in it but what I have referred to—matrix and corpuscles. In bone there are abundant bloodvessels. Now, apparently, by the nearer approach of the bloodvessels in a growing bone, the cartilage-corpuscles find they are getting into a rich country full of sap, and they take to growing. That is the general explanation of what occurs. What is seen is, that a little nearer the ossifying edge than the scattered single corpuscles there are bunches of corpuscles which in section are lozenge-shaped. (Plate I., Fig. 1.) Each of these masses consists of the progeny of one such corpuscle as those above it. A little further down, each of these lozenge-shaped masses is replaced by a larger mass, and still going nearer the ossifying edge, you come upon larger and larger corpuscles arranged in groups which have changed their shape by stretching out into columns.

Now, consider what all this involves. Changes are taking place in the heart of the solid cartilage, in the region where the lozenge-shaped groups, of such a sort that where there was one little microscopic body in the middle of stiff matrix, there come afterwards to be two, with stiff matrix round about each. The same swelling of parts is going on in connection with the corpuscles nearer the ossifying edge, though the multiplication in that part has ceased for a time. All this means that undoubtedly the stiff substance already laid down is being pushed aside by new material, and that every particle of the cartilage is set in motion by the activities of the corpuscles that are contained within it; and in this way is illustrated a point which we have much more evidence of, that cartilage grows by interstitial expansion. Even in the heart of the mass expansion takes place freely. It looks at first sight

impossible that such a firm substance should be pushed aside by such minute structures as the corpuscles in its interior. But that there is such change actually going on is evidenced by microscopic appearances in every growing block.

Bone, however, is harder than cartilage. It has got a very large amount of mineral matter in its constitution—two-thirds of its weight being derived therefrom. If you take a mass of bone and steep it for months in muriatic acid you get rid of all the mineral matter; but neither the shape nor the microscopic structure is affected.

This [exhibiting a specimen] was a hard bone once, and retains its size and shape. You recognise in it a lumbar vertebra. But it is quite light; it can be squeezed together like a sponge, and resumes its size, because all the mineral matter with which the tissue was impregnated has been removed. So uniformly is the mineral matter distributed in the matrix of bone that it does not prevent the passage of the light through thin sections. Bone can be as easily examined by transmitted light as cartilage can be, and no evidence is afforded of the way in which it is deposited, even when we look with the highest powers of the microscope. Where cartilage is being converted into bone and the mineral matter is beginning to be deposited in it, the translucency is lost in the region of the columnar groups of corpuscles, where you find the gristle breaks away easily from the bone; and microscopists find this region difficult to deal with, until the mineral matter has been removed by means of acid. The reason of this is that the mineralised substance is in exceedingly minute patches, or granules, making, as one may say, so many spherical lenses of denser substance imbedded in a substance less dense. But when acid is added, the granules disappear and give place to uniform translucency, showing that they do not consist of pure mineral matter, but of mineralised animal matter, which, apart from its mineral impregnation, is exactly the same as its surroundings. Each is a little mass of bony substance, similar to that which afterwards forms the whole matrix of bone.

Now with regard to the ordinary nourishment of bone there is a difficulty as compared with cartilage. For although a few observers have brought under notice, over and over again, that there are complicated patterns in the matrix of cartilage, giving indications of channels more habitually made use of by the

currents of nourishment passing from one corpuscle to another than are the territories between, yet, notwithstanding this, it remains true, as is seen with ordinary methods, that there is unbroken continuity of matrix. But in bone the arrangement is different. The corpuscles are no longer incapsuled, but have numerous branches, and the substance in which they are imbedded is closely threaded with minute passages, by means of which the space containing one corpuscle communicates with others. (Fig. 2.) We call each space containing a bone-corpuscle, a *lacuna*, and the fine connecting canals, *canaliculi*. Sometimes the canaliculi are so wonderfully numerous as to be quite uncountable. They look like a rich head of hair combed out in different directions from each lacuna. It is liable to be taken for granted that they are formed round the branches of the corpuscles. Certainly some of them are so, but I think it must be an open question in the minds of most of us whether the whole of them are formed in that way. What is important to notice is that, owing to the exceeding density of the matrix in bone, it has become necessary that it should be broken up by a great number of perfectly definite canals, to allow sap to pass from corpuscle to corpuscle. There is thus an alteration in the character of the matrix as compared with that of cartilage, as well as an alteration in the character of the corpuscles, to allow of their ordinary nourishment; and the question with regard to the growth of bone which I specially had in my mind to speak on was, how this exceedingly dense texture was able to increase in size.

The most important points in answer to this question have been known to science for a very long time; in fact, John Hunter made numerous and conclusive experiments on the subject. Briefly, the difference between the growth of bone and the growth of cartilage, or any other tissue, may be put thus:—A mass of compact bone is not capable of being enlarged by multiplication of the corpuscles in its interior, nor by any forces of growth going on inside it; its increase in size is brought about altogether by additions at its circumference. I may perhaps best illustrate this by mentioning two experiments, both of which were made by Hunter. In one experiment he cut down on the humerus of a young pigeon. He passed a silver wire tightly round it, and put the little wound together, and the pigeon, none the worse, was, without the permission of any Secretary of State, allowed to live and enjoy life until it had grown, when, like most pigeons, it

came to an untimely end. When the humerus operated on came to be looked at, there was no silver ring to be seen till it was cut open, when the silver ring was found loose in the interior.

A bird's humerus is different from a mammal's, in respect that a mammal's humerus has a much greater thickness of bony substance, and is filled with marrow; while, in the bird, to make it lighter, the bone is exceedingly thin [exhibiting a specimen], almost like paper, and not only so, but it is filled with air, which it gets from the lungs by means of a special apparatus, and enters the humerus by a hole of very considerable size underneath the articular head. A bag continuous with the breathing apparatus pushes its way in at this aperture when the bird is young, and expands until it fills up the whole interior of the bone.

Now, to return to John Hunter's experiment. The circumstance that the silver ring was found lying loose inside shows that all the bone which had been originally grasped by it had disappeared. But while it was disappearing new bone was added in layers outside, and surrounded the ring. Here is a thigh bone of a rabbit in which, in like manner, new layers of bone have covered over a silver ligature. Thus we gain the information that a shafted bone increases in thickness by additional layers growing outside what has already been deposited; and further, that the marrow-cavity in a mammal, or the air-cavity in a bird, is formed by absorption of the bone previously existing. It might be thought that the walls of the young bone expanded as they grew bigger, got stretched out by some force so as to have a larger cavity in the interior than they had originally surrounded. But it has become evident that this is not the case. They disappear altogether, and new walls are formed.

So much for the growth in thickness. To understand growth in length it will be necessary to note that the shaft and the two extremities are ossified from separate centres, and remain long distinct. The shaft we call the *diaphysis*, the bony growths at the extremities, *epiphyses*. This arm-bone [exhibited] which I show you is long enough to belong to an adult, but it is not quite adult, for, as you see, the ossification has not been completed. There has been a very thin layer of cartilage between the shaft and each epiphysis, which has been removed in the process of preparation, so as to allow the three parts to fall separate. This is a condition which, as I mentioned, you have abundant means of studying in the lower animals, by using the opportunities which our habits of

diet give. Now, during the years in which the length was increasing, the lines of separation between the shaft and the epiphysis were gradually retreating from one another. The question comes to be—How was the shaft increased in length?

John Hunter's plan of trying to find the answer—a plan which has been repeated with modification by many others—was to insert shot at a measured distance in the bone of a growing animal. The wound was healed, and the animal kept alive until it became an adult, and it was found that though the bone had increased in length, the shot remained at exactly the same distance as when they were inserted. Thus it was proved that the shaft was increased in length by additions at the expense of the thin cartilaginous plates at its extremities; while there was no expansion in length of the bony matter already deposited, any more than in thickness. This doctrine has been denied even in our own time, but the denial has only brought other experimenters into the field, with the result that Hunter's views have been amply confirmed.

One experiment has been made which may interest you. The rabbit has in the fore-arm a radius and ulna similar to what we have. The lower end of the radius is thick, while the lower end of the ulna is slender, and both bones have an epiphysis at the lower end. You will notice that if a shaft can only be elongated by additions where it is in contact with cartilage, its increase in length will cease when the cartilages are converted into bone. Founding on this, a German experimentalist, a good many years ago, made an experiment in the following way. He passed a needle into the cartilage which separated the lower end of a young rabbit's radius from the lower epiphysis, and so irritated it that it became converted into bone. But he left the ulna uninjured, with the result that after a time the fore-paw was completely turned inwards by the radius ceasing to elongate, while the continued elongation of the slender lower end of the ulna had power to push the outer side of the paw before it, distorting the limb and making the rabbit bandy-legged.

It is specially in compact bone that the peculiarities of growth which I have placed before you occur. It may be interesting for you to know how the ordinary process of nutrition goes on in that variety of bony tissue. If you look at a transverse section of a long bone, you find that the microscopic appearance is not uniform. The lacunæ and canaliculi are arranged in laminated fashion,

and especially you see concentric arrangements of laminæ round canals. There are such canals, containing bloodvessels, pervading the whole mass. They are called Haversian canals, after an old English physician, Clopton Havers, who was the first to detect their existence, but knew nothing of their contents. He described them as being for the animal spirits, and knew they were for the spirits because they were oily. The laminæ are disposed concentrically round spaces containing vessels, until at last the vessels are tightly surrounded by the innermost; and each such arrangement of laminæ round a vascular canal constitutes a Haversian system. Further, in young animals there are always, underneath the periosteum, regularly disposed lamellæ going round the whole bone. It was by these outer lamellæ that Hunter's pigeon's bones grew in girth; but if you had growth only of this description, you never would have the complex arrangement of concentric laminæ round Haversian canals, which form the main mass, and are packed together by portions of other concentric arrangements, whose rings are cut across by them. (Fig. 3.) For you not only see Haversian systems, in which lamellæ are arranged concentrically around a central canal containing one or more bloodvessels, but also series of laminæ abruptly cut across by more complete systems, and in many places not by any means parallel to the surface of the bone, or parallel to the marrow cavity in the interior of the bone, but forming portions of circles so small as to indicate that they themselves belong to pre-existing Haversian systems. You find, further, that you often meet with cavities of considerable size with only one or two lamellæ round them. These contain, among other things, corpuscles, sometimes called osteoblasts, by means of which new bone is formed from the soft tissues. These, in time, become completely imbedded in the bony matrix which they throw out.

The next set of corpuscles which will be developed on the osseous surface will get surrounded in the same fashion, till the concentric rings closely surround the bloodvessel. Such an open gap is what may be called a Haversian space, as distinguished from a Haversian canal, whose system of lamellæ is completed. There is another appearance regularly met with, consisting of hollows not surrounded by any laminæ arranged evenly round their circumference, but having ragged edges. On examining near the circumference of these cavities, there are always to be seen

enormous numbers of nucleated corpuscles, and very often five or six or more nuclei, in what appears to be one mass of protoplasm. These have been described as a separate order of giant corpuscles, having a special absorptive function, but, in reality, we have all along to deal with one race of corpuscles, which, in certain circumstances, take origin in soft tissue, and arrange themselves round surfaces of already deposited bone, to become themselves imbedded in osseous matrix; while at other times, being closely encompassed by bony matrix, they enter on a state of renewed activity, their nuclei multiplying, but the surroundings preventing the protoplasm breaking into separate masses, until it has made room by absorbing the bony matrix around.

The process of re-absorption of bone matrix may begin at a lacuna, or in a Haversian canal, or beneath the periosteum, or in the walls of the marrow cavity. But the Haversian systems are always produced by the eating away of bone which has been previously deposited, and the subsequent deposit of new bone, commencing in layers round the absorption-spaces, and proceeding concentrically till at last the spaces are completely filled.

Perhaps the most curious thing connected with bones is that this structural change is going on with a degree of rapidity which we do not yet clearly estimate, but is going on either more rapidly or more slowly all through life. It is only by this means we can account for the number of Haversian systems, perfect and partially obliterated, which we see brought together. The wasting of bones in old age is just performed by the same processes that have been going on through childhood and adolescence, and continued in the adult. The only difference is that absorption fails to be supplemented by redeposition. The special peculiarity running all through the history of bone, whether in growth or in old-age-wasting, or in the maintenance of the form in adult life, may be summed up in this:—that a mass of bone once laid down, however small it may be, is incapable even of allowing a single corpuscle to multiply into two or a larger number without there being at the same time a reabsorption of a certain amount of matrix; and this arises from that want of expansive power which Hunter's experiments proved as the characteristic feature of bone in the gross.

#### DISCUSSION.

DR. JOSEPH COATS said—I think it would be a pity to spoil the impression left on our minds by Dr. Cleland's very clear

account of the process of the growth of the bones by any extended remarks; in fact, it would be impossible to criticise his paper—one can only have listened to it with the warmest appreciation. There is one thing which I may venture perhaps to add to what he has said. All these processes he has been describing so clearly to us are going on consistently with, and in the midst of, the functional activity of the bones. There is always a taking down and building up, and yet our bones are used, and used in young animals, I should say, much more vigorously than in adults. Throughout all the period of growth, involving these diverse processes of construction and reconstruction, the bones have to bear the continuous stress to which they, as the mechanical supports of the body, are exposed. In regard to the architecture of the bone, I was very much interested in reading a paper by Meyer of Zurich, in which he, with a series of most beautiful photographs representing sections of macerated bones, illustrated the internal structure of the bones. This showed that what we call the cancellated tissue at the ends of the long bones, and the whole of the interior of short bones, is not merely an indefinite mesh-work like a sponge, but a beautiful system of supporting columns for resisting the pressure to which the bone is exposed. By the merest accident I had an opportunity of seeing Professor Meyer's preparations while in Zurich, and was able to convince myself of the truth of his statements. The striking thing is, that while the bone is growing, and growing by this process of absorption and deposition, all this beautiful architecture is preserved. Meyer uses this fact as a very strong argument to show that the growth of bone is not by interstitial expansion, but by absorption and deposition; but his argument in that respect I need not go into.

The PRESIDENT—If no one has anything else to say, I shall make one or two brief observations. In the first place, we are much obliged to Dr. Cleland for coming here to-night and giving us this valuable communication. I know he has been making the subject of the growth of cartilage and bone a special study for a considerable time, and we are much favoured by receiving from him, at first hand, the results of his research—results which are all the more important from the fact that Dr. Cleland is a scientific worker who gives much interest, freshness, and originality to everything which he investigates. I have always been very much struck with the growth and development of bone. The story of

the growth of bone is one of the most interesting stories in physiological science. Dr. Cleland, at the outset of his remarks, referred to the fact that we know very little, indeed next to nothing, of the more intricate process by which the tissues are formed; and this is, no doubt, quite true. It is this region, however, that by and by we may hope to be able to penetrate. We have seen how these bone-corpuscles perform their marvellous work of building up the texture of bone, and of pulling it down again, but we must investigate, in the next place, how they perform this work. Each one is a mass of protoplasm, presenting, under the highest microscopic power, no special textural peculiarities that can explain its properties; and yet how marvellous it is that this little nucleated mass should have the power of separating from the blood the salts of lime that are dissolved in blood, and of precipitating these into its fibrous texture. And not only can it do this, but it deposits these little particles in a definite manner, and, after these have served their purpose, as Dr. Cleland has illustrated, the same kind of granular living masses pull it down. In other words, they have some peculiar power of redissolving the salts of lime, some of which are by no means very soluble, so that they are taken into the blood and carried away. There you have little bodies of granular living matter capable of performing this remarkable chemical process, and the physiology of the future will have to explain how these little masses of living matter can perform this work. The wider we take our survey of what is going on in nature, the more likely we are to get light upon a difficult problem like this. Bone is not the only substance in which we find living matter exercising powers over mineral matter. We know that many of the lower forms of life, lower forms of invertebrates in the sea, for instance, such as sponges, foraminifera, and others, secrete earthy salts from the sea water, so as to form minute shells of exquisite forms, and in which both salts of lime and silicious matter are deposited. There you have the process going on in the lower forms of life. Here in the bones of the higher animals you have a process of the same kind going on. I have no doubt that you will not readily forget—even those of you who have not studied this subject—Dr. Cleland's address. Many are apt to think of bone as a tissue in which active changes are not going on; at any rate, they do not think the changes are going on with great rapidity. But Dr. Cleland has demonstrated that, in early life especially, but also

throughout the whole of life, in every cubic inch of bone substance there are tens of thousands of minute corpuscles busily engaged in the work he has described. If you have not studied the subject you are apt to form an inadequate conception of the minute size of those organisms. The corpuscles are not larger than the 2000th or 2500th part of an inch, and even the so-called "giant cells" are very small things; yet it is by the incessant activity of these minute organisms that our bones grow. I was glad to hear Dr. Cleland express the view that our bodies, strangely complex as they are, represent a commonwealth of living things, each to a certain extent independent, and yet all working for the good of the whole. These are all engaged carrying on this work; but how little we do know of what guides them in their various movements, or the processes they carry on! In your name I return him our thanks.

IV.—*The Scientific Cultivation of the Senses*. By W. ANDERSON  
SMITH, Member of the Scottish Fishery Board.

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[Read before the Society, 20th January, 1892.]

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OWING to the necessary rigidity of a system of imparting information regulated by grants, popular education has lost the old elasticity, and has not yet risen above the old-fashioned idea that teaching and education are synonymous. Our educational leaders are not ignorant of the great want in the common teaching of the Board Schools, but they have not hitherto suggested a ready remedy for the lack of initiation and systematisation. What is especially apparent is the absence of systematic training, or cultivation, in the ordinary schools; and this ought to be supplied in such a manner as could be readily taken advantage of by the general body of children. At present the steady and continuous effort to impart second-hand information induces a belief in the minds of all concerned that this is really education; and most pupils continue to rely upon this second-hand education, to the destruction of originality and confidence in their own observation.

We have scientific system in our physical gymnasia, and in our higher mental training in logic and philosophy, or mathematics,—a training of faculties without regard to the direction of their future application; but between these two extremes all is “rule of thumb.” The greatest hiatus in our ordinary education, therefore, is the absence of system, and the training of faculty as such; and this gap we propose to fill by the scientific and systematic cultivation of our senses.

All knowledge, even the ability to gather second-hand knowledge, can only be obtained through our senses; and our “no-system” at length leads the ordinary student to rely mainly upon the one specialised sense of sight, as applied to reading or acquiring second-hand knowledge, until he gradually loses all faculty for exact and reliable first-hand information, and his observations become untrustworthy.

To reach the mind through the great natural channels of the

senses, by cultivating these systematically, is the immediate object of the new system proposed. It has long been felt to be a desideratum, without the necessity being properly formulated. Thus Professor Bain writes:—"The exercise or training of the senses is much insisted on, but is not well defined. Here, too, there is a general training suited to all, and a special training for special arts. To train any one of the senses is to increase its natural power of discrimination, as in colours, tones, touches, odours, tastes. . . . Out of this superior discrimination will grow a better memory for the respective sights and sounds and tastes, so that the conceptive concrete faculty will be strengthened at the same time." For, as Dr. Bain elsewhere observes, "even long after a child can read, it is unable to extract much information from books." Still he does not see a way out of the difficulty, for: "At what time should we begin the mechanical training of the hands, the training of the voice, the training of the eyes in observing colours? We here proceed upon a natural spontaneity, which needs directing and coercing; the coercion being more or less painful in itself, and palatable only by the interest evoked." This latter is a point to be specially aimed at, and which my system successfully accomplishes, being to the senses what mathematics or philosophy is to the higher mental development, and stimulating the intellect systematically, and yet agreeably, in its early stages.

According to Bernstein, "the sensory organs are only instruments of the mind, which has its seat in the brain, and by means of nerves makes use of these instruments to obtain information of external objects." Again, "the sensations of the senses appear to be of a higher kind than the common sensations. The general sensibility of the body is, indeed, the general ground from which the sensations of the senses also spring; but they are distinguished from it by a more complete perfection, since they are produced by the action of the forces of the external world upon delicately constructed organs on the surface of the body, and the *mind* is thereby brought into immediate communication with the external world." The great importance of sense-training, therefore, is apparent and acknowledged by authorities, but it has not been given effect to systematically and fundamentally. In regard to the *Kindergarten* system, with which it has been compared, Bain writes:—"This should not be called *sense-training*; it is a special education in drawing and design."

Bernstein is very distinct in his statements as to the character of our senses. He says:—"We see that it is by the activity of the *Mind* alone that the *Sensations* of the senses are converted into *Perceptions* of the senses;" and again:—"He cannot help conjecturing that the perception of the external world is essentially an act of the mind, which has its seat in the cerebrum, and is connected with this organ; and further, that the sensory organ with its nervous connections only affords the brain the material which it converts into a sensory perception."

It does not seem to matter which sense we commence with in a system of cultivation, although the sight is the one that is commonly most progressive. I agree with Bain that:—"The cultivation of distinct organs or faculties may proceed without any fixed sequence. There is no settled order as between colour, form, and number." But I demand that all should be dealt with as we proceed. In insisting upon the importance of systematic and fundamental *sense-culture* at the outset, in place of proceeding to the *sense-athletics* that some progressive teachers have adopted, I merely proceed upon the same principle as those who demand the multiplication table as a basis for arithmetic.

What the multiplication table is to the science of numbers, what Euclid or logic is to abstract thought, so I claim is my scientific system to the application of the senses, not only to the ordinary affairs of life, but to all technical and scientific processes. Without this prior groundwork, natural gifts may triumph, as a strong intellect may also do without either logical or mathematical training; still, they will not only do so without assistance, and consequently at a disadvantage, but even in defiance of that obstruction which comes of disuse and concentration of faculty in other directions.

By means of *sense-culture* a foundation is laid for the ultimate refinement and cultivation of all the connections between the external world and the human intellect; and further, for the special development of those intellectual aptitudes more or less depending upon them. It is somewhat of a paradox that, while our modern science is one of first-hand knowledge, our modern education should be so completely second-hand, with the result that the multitude are forced to accept somewhat blindly the observations of the few, in place of being prepared to receive them cautiously and test them carefully. Thus it is, that while authority as a power may be said to be dying daily, the only

proper substitute—namely, careful, skilled, personal examination, does not take its place! We create the necessity, but fail to supply the demand, the very efforts after second-hand knowledge destroying the power to acquire this first-hand knowledge through our blinded and neglected senses.

Under ordinary circumstances the town-dweller trusts more to his daily paper than to his daily observation. The sight that in the native hunter or path-finder is as exact as it is all-embracing, can scarcely be expected in a state of society where so many require artificial aids to sight to enable them to perform suitably the most superficial daily labours. And yet individuals in certain arts have developed an accuracy and minuteness of vision beyond that of the keenest savage. The same may be said of the ear, for the most startling feats of Fenimore Cooper's ideal redskin fall short of those of a skilled musician, or of a specialist with the stethoscope. Again, a tea-taster or a connoisseur in wines is trained to a delicacy of palate which no untutored mouth could pretend to; and yet, as a rule, we are satisfied with the lowest general average faculty in all these directions. There is no scientific development of our ordinary senses as a rule, even the artist and biologist are not regularly cultivated up to exactitude and certainty, but reach it in a haphazard way; and the "ear" of the musician is more looked upon as a natural "gift" than as an embryo faculty with infinite possibilities. We not only do not cultivate, we violently assault our senses. Let alone the violent treatment the palate receives from boiling liquids, cayenne pepper, curries, or strong sauces, we have numerous other refinements of torture. I believe greater attention even to the sense of taste would do much to simplify and refine our lives, and lead us to find the pleasures of the palate in a purer, simpler, and more natural diet. What is wanted all round is systematic attention, in place of neglect and inattention; so soon as the intellectual world gives due consideration to the subject, this gap in our educational system will be filled up.

In order to secure this scientific sense-culture that I have indicated, the senses must be looked upon in an entirely different light from the higher mental faculties. In normal children the senses are, as a rule, already highly sensitive and developed. What is required is to utilise them as mild brain stimulants, as Nature uses them, but with the system and progressive regularity that constitutes true education. There will thus be trained

what Dr. Bain calls the "conceptive concrete faculty," and at the same time the judgment will be constantly called into exercise in coming to a decision. I have sought to reduce the exercises for the different senses to the simplest form, and to eliminate from the exercises for each sense any possibility of shirking its exercise by the employment of another and better qualified sense.

At the same time, by the employment of comparatively delicate apparatus, a certain refinement is demanded or produced, and what is essentially a fundamental system of sense-training becomes almost of necessity an æsthetic education as well, all the more effectual, perhaps, because it is unconscious and basic.

The sense that may be first considered is the so-called *muscular sense*, and for convenience of training this may be considered in two sections:—

(1) *Sense of Weight*.—The faculty of calculation of weight is of great value in all departments of life, and its applications are numberless. It is more especially connected with the practical habit of mind, and its due cultivation is an introduction to one of the principal qualities of matter, such as cannot fail to be of utility to young and old of both sexes. By a series of graduated weights placed in small cases, so as to be varied in extent of graduation with the capacity or progress of the pupil, the sense of weight is cultivated systematically, and calculation called forth in order to decide upon the relative differences. I prefer that these cases be as light as possible, and have no special connection with standard weights. The object is to train a faculty, not to teach special knowledge of particular weights. The lightness of the cases and the general delicacy of the articles employed in these exercises cultivate a delicacy of handling of great importance in technical work.

(2) *The Sense of Pressure*.—To a small extent this is called forth even in balancing and calculating the several cases of varying weight; but I prefer to have it trained still more fundamentally, and for this purpose employ a small lever on a movable fulcrum, by which the same graduated cases are tested and set in order by pressure of the finger on the lever, upon the other end of which the cases are successively placed. By moving the fulcrum so as to lengthen or shorten the leverage, the difficulty may be lessened or increased. This is as nearly pressure alone as the former exercise is weight alone, but to a certain extent they intermingle. The knowledge of a mechanical power

thus imparted at the same time is entirely subsidiary, and not connected with the system except incidentally. The imparting of knowledge is not my purpose, but the training of faculty ; and whether it be in handling a hammer, a pencil, an adze, or the keys of a piano, the pressure sense is one of the utmost value and is in constant exercise. But to cultivate this faculty—the whole muscular sense—the training ought to be progressive and systematic, and to begin at an early age. A cognate sense is :—

*The Sense of Touch.*—This is left commonly to later life and technical pursuits to educate, in place of commencing when the sensations are keen and the capacity for culture great. For a child is all sensibility, and at the earliest age begins to use its hands to “feel” for knowledge. It is long before the constantly reiterated “don’t touch !” educates the child out of a most useful natural instinct, the employment of one of its avenues to knowledge. Only when the sense has greatly deteriorated, and the youth has chosen his vocation, does he set about seeking to regain a partially-lost faculty. The delicacy of touch and power of discrimination of those engaged in some textile trades, the refinement of touch and exactitude required in the microscopist, the surgeon, the biologist, or the physiologist, are all the result of simple and direct application—they are not worked up to, or based on an original scientific footing. Yet such a culture is a greater advance towards technical knowledge, through technical faculty, than direct technical teaching can as a rule be. At present the hand of the draughtsman or craftsman is educated technically, in place of being prepared from the earliest days—more especially in refinement. I propose to train the sense of touch much as that of the blind is trained, but by a still more simple system. An instrument is provided pointed bluntly at one end, and like a bradawl at the other. By slightly damping a piece of cardboard or thick paper, the letters of the Morse Alphabet—which is perhaps more justly Lord Bacon’s Alphabet—may be slightly raised on the opposite side by means of the instrument noted. By commencing with single dots and strokes the finger becomes accustomed to the sensation, and groups of the two figures become decipherable at one operation. By increasing or decreasing the depth of the impression the exercises may be made progressive in difficulty, as well as by the multiplication of the signs and their closer proximity. Delicacy need not be gained at the cost of strength. The hand of a baker becomes equally

delicate, tough, and strong. The cultivation may be carried to any extent by progressive exercises in textile fabrics, and otherwise.

*The Sight*, or sensibility to light waves, has been more attended to than most of the senses, from the readiness with which it is injured, and the helplessness caused by its absence or injury. But, as in the case of all other ailments, more attention has been devoted to cure than to prevention, and its early culture has been as little systematised as that of any other sense. In place of being improved by our school curriculum, it is generally injured. Systematic sense-culture will necessarily discover the aptitudes of the pupils, and their strength, peculiarity, or weakness of eye will naturally show itself.

Cultivation of the eye, or sense of sight, requires to be on several lines. Extreme exactitude and nicety of eye can best be trained by threading a series of needles, of increasing fineness, with quickness and certainty. Even in girls' schools this is not attended to, the ordinary school-work not demanding the use of the finest needles. Yet the regular use of such a series would sharpen the sight and help to keep it acute. Its technical utility is self-evident. Then the nicety of discrimination demanded in classifying the different shades of the same colour is best obtained by systematic practice, and this may be imparted by close attention to the shades of greys up to black. What is here required is the habit of attending to the subject, and the practice of carrying the different depths of shade in the mind. This latter is cultivated by numbering a set of graduated cards, and learning to tell the number or quality of shade. Red, green, and violet are perhaps the best colours to employ.

*Size and Form.*—The next step may be the cultivation of the eye for size and form. Although a necessary every-day, as well as engineering, faculty, this judging of form is one of the rarest of qualities. We lift some article to fit in a given place, and find it "far out." We cut some piece of cloth, or paper, or wood, or iron, and find it so much too small that it is spoiled for its purpose. Yet this faculty of judging of, and remembering, form is the one most in demand in acquiring an acquaintance with the natural sciences. Until the eye can readily discriminate between the forms of the different leaves, the character of the several stems, and all the other external points of difference, the botanist can have no idea of genera or species. Until the eye of the

anatomist, the microscopist, or the zoologist, or indeed the worker in any other department of natural science, is trained in a "form sense," he can make no real progress. Yet the most unscientific part of science is the lack of special preparation of the senses, although these senses are so indispensable for its advance.

There have been useful attempts at dealing with form, but they begin where my system ends. I refer to the putting together of maps, of brick houses, or of other such modes of *employing* the sense of form; but they do not systematically cultivate it. This I do by commencing with simple exercises with simple figures, such as a progressive series of circles to be rapidly graduated, advancing to more difficult and complex forms.

From this I pass to *Proportion*, one of the most valuable mental faculties. Even the sense of artistic proportion, that is supposed to be a natural "gift," and is so in its highest development, is based upon a simple mental quality with a sense-outlet, or inlet, through the eye. By commencing systematically with sets of figures of a simple character, such as the square or the triangle, we are led to note the slightest variation from the true form, and may thus be led up to an estimate of the proper proportions of the most artistic combinations. To plunge a pupil at once in *medias res*, and declare he has no artistic sense of proportion because it cannot thus be reached, is worthy of the dark ages, ere modern science dawned upon humanity.

*The Sense of Hearing.*—With all our attention to music, the average ear is not trained. A musician may have the nicest ear for harmony and time, and yet be unable to tell the distance, the direction, or the force of a sound. He may fail to hear the note of a wren, a tap at the door, or a ring at the bell. The usual ear-training is technical, not systematic throughout, and thus how few medical men, brought to make the effort at a certain maturity, can differentiate the finest variations of the pulsating heart, or the breathings of the delicately injured lung. Still, the dullest ear may be greatly improved by the habit of attention, and by an effort, systematic and continued, to catch the vibrations impinging on the drum, and read their character. As it is especially desirable that these in the first instance should not be harmonic, I propose to use the weight cases as an exercise. By dropping these on the slate, or a plate of glass, the difference of sound may be noted, and the series set in order accordingly. For more delicate sounds the impinging of a pellet upon a plate of glass,

from varying distances, as marked on a graduated card, will supply the necessary exercise. In this way the ear is trained to discrimination, apart either from time or tune.

I do not mean to enlarge on *Smell* and *Taste*, both extremely important and only too much neglected. Discrimination and delicacy are what are required, and they can be taught as well by refined preparations of one or two simple chemicals, as by any number of scents and flavours. It is the principle of regular systematic advance on the simplest lines, so as to keep the sense doors open and the sense faculties on the watch, that I specially advocate, and my system is thus as far as possible fundamental. In conclusion :

*Sense-culture* discovers the aptitudes and deficiencies of the pupils, enabling the one to be made the most of, and the other to be improved. It trains the faculties systematically and fundamentally at a time of life when the mind cannot well be reached by any other system. This it does, too, agreeably, almost imperceptibly, by interesting the pupils in the operations required. It gives the young mind that idea of systematisation that is the true basis of all education, while it can be applied to the youngest. I therefore present my system as a first attempt to solve, scientifically and practically, an undoubted problem in present-day education.

V.—*The Sewage Problem in Villages and Small Towns.* By  
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College.

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[Read before the Society, 30th March, 1892.]

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ALTHOUGH, in its broad features, the sewage problem is the same whatever the size of the community, and although its solution depends upon the same natural principles, there are still so many differences in the application of these principles that it is, I think, worth while to look specially into the question as it affects smaller communities. The large towns have either settled their sewage problems long ago, or they have, at least, been struggling with them for a long time, but many smaller places are only now waking up to the consciousness that such a difficulty is before them; and the progress of sanitary science makes it certain that before long they will have to face it, and decide how far the methods of larger places are suitable for them, and to what extent modifications must be adopted. I did not take up this question with the expectation of introducing anything novel, but because on various occasions I have seen instances of division of opinion, of uncertainty of opinion, and of doubt as to results. All that I hope to do is to take up some of those points, to consider what has been done, and, without presuming to pass final judgment, to trace them to the principles on which that judgment should depend.

In a large town the sewage difficulty consists in the immense volume with which we have to deal, and the apparent impossibility of finding, at any cost, a thoroughly satisfactory method of treatment. In a small place the difficulty is of a different nature. The volume of sewage produced is not large, the works required for its removal and disposal are not elaborate, and the whole treatment, so as to secure satisfactory results, would be easy, if a small fraction of the amount spent in a large town were available in the small one. But although the absolute cost may be small, it would be large in proportion to the available funds, and a place where a penny of assessment only yields £30, £40, or £50, has to

look to an expenditure of hundreds more closely than a large town does to thousands. And as to disposal, unless the simple plan of running the sewage direct into the sea is adopted, there is, on the one hand, the chance of interdict if a river is used as the receiver, or if, by a too primitive system of irrigation, a nuisance is created; while, on the other hand, to adopt more modern methods of disposal requires more or less attention, and this, in a small place, may be a matter still more serious than the capital expenditure. The employment of an additional man may make, from the ratepayers' point of view, all the difference between economy and extravagance. The difference practically comes to be that while in a large town ample resources may not be sufficient to cope with the difficulty, the question in a small place turns very largely on expense.

Although the water-carriage system is the one that concerns us now, it must not be forgotten that in many places this system is only very partially in use, and although it is rapidly extending, there are still many districts where removal by hand is necessary. I would only say, with respect to the latter, that, in order to be a sanitary success, it is absolutely essential that removal should be frequent, that the receptacles should be small, and that precautions should be taken to prevent the wholesale pollution of earth and water. Practically, the removal must be under official control. With proper arrangements, there is little fault to find with removal by hand; but the old system, which unfortunately still exists in many places, of accumulating for months a putrefying mass of rubbish and filth in the immediate vicinity of almost every house, is one that cannot be too strongly condemned. It is, however, chiefly with water-carried sewage that we have to do, as sewers cannot be dispensed with in any populous place, even if much is removed by hand.

Of the two parts into which the problem is divided—sewerage and sewage disposal—the former has so far attracted most attention. The latter, however, is every day coming more to the front, and is sure to become in many places a very pressing question. Although the two are distinct, they have an important bearing on each other, for the feasibility or otherwise of a system of disposal may depend altogether on the method of collection, and it is therefore necessary in any inland scheme, at all events, to keep in view during the carrying out of the sewerage the possibility that works for disposal may sooner or later have to be added.

Leaving that question, however, for the moment, we may take up that of sewerage, which, although a very old acquaintance, is constantly assuming new phases. I do not propose, of course, to refer to matters which are elementary parts of an engineer's knowledge, such as the general considerations of shape, material, gradient, and size of sewers. The matters which I do propose to mention are some which are less conspicuous, and regarding which there are differences both of opinion and practice. Some of these have come directly or indirectly under my own observation, and while attending the meetings last autumn of the International Congress of Hygiene I had the opportunity of hearing some of these points discussed by those well qualified to form opinions.

The first of these points is the connection between sewage proper and surface water, and the admission or non-admission of the latter to the sewers. Much may be said in favour of admitting it altogether. It avoids the inconvenience of a double system of conduits, and the rainfall forms a very effective flushing agent. But there are, on the other hand, serious disadvantages. Apart from those connected with sewage disposal, which will be afterwards referred to, there is the serious fact that the sewers require to be made large enough to carry not only the sewage proper, but the rain-water as well. The former is by no means a constant quantity, but it has a maximum tolerably well defined; while the latter is not only extremely variable, but frequently exceeds by many times the volume of actual sewage. As the sewer has to be large enough for the maximum flow, it follows that it is for most of the time acting as a reservoir for gases more or less foul—a state of affairs made more serious by the fact that while a heavy fall of rain no doubt flushes the sewer, it also coats its whole surface with putrescible matters.

For two reasons this objection to the combined system applies with more force to small than to large places. The first is, that in a small place the sewers are generally too small to require the use of anything but pipes, and as these are almost necessarily circular, they are ill adapted for a very variable flow. The other is that in a small place the density of population is less, and, therefore, other things being equal, the proportion of rainfall to sewage is greater; and this difference is intensified by the fact that much of the rainfall in a rural district reaches the sewers or water-courses in a tolerably clean condition, while in a large town the rainfall is practically no better as regards purity

than sewage. It is generally recognised, therefore, that for rural districts the separate system, modified to suit local requirements, is usually desirable.

There are several considerations, however, which prevent its being carried out in its entirety. In poorer districts it may be assumed that the street gullies will be utilised to a great extent as sinks, as may be observed by walking through the back streets of any town or village. These gullies are, therefore, receptacles for sewage, and, as such, must be connected with the sewage system. And again, in houses which have any system of drainage, the water from roofs, courts, &c., is naturally led into the house drains, and so into the sewers. Any attempt to carry the system of separation to this extent would involve large expense, and would, besides, do more harm than good. The plan which is usually most economical and efficacious is as follows:—There is generally in any district in which a sewage scheme is proposed a set of drains of some sort, discharging more or less directly into the natural water-courses of the country. These drains, when used for sewage, become what are called “sewers of deposit,” and, in fact, very often include some old water-course, arched over so as to hide its filthiness from sight and smell. In such a case it is often desirable to allow these old drains to remain, but to restore them to the condition of rain-water channels. By this means the rain-water is allowed to find its way without much hindrance to the river or stream, while, by a system of intercepting sewers, the actual sewage is collected for what treatment may be necessary. It must be remembered that, although the bulk of the rain water is kept out of the sewers, and, therefore, that these may be made much smaller, a considerable proportion will find its way into them, and a volume of several times the actual sewage must be allowed for.

There are other matters to be considered. A small place has more trouble than a large one as regards gradients. It is well enough known that with a large volume of sewage a flatter gradient will give the required velocity than when the volume is small, and although we occasionally come across instances of sewers being made large in order to counteract insufficient gradient, quite indifferent as to whether there is sufficient sewage for them to carry, such gross mistakes will not be made by any but an amateur engineer. The velocities as given in tables and by formulæ, refer to pipes running either full or half full, and

not to a trickle along the bottom. Assuming, however, that the size is properly proportioned to the volume of sewage, and that the pipe is laid with an inclination not less than would be sufficient for a pipe with a steady flow, a pipe in a sparsely populated district is in an exceptionally bad position. The conditions, in fact, approach very closely those of a house drain, and no man in his senses would lay a house drain, without very special precaution, at a gradient even distantly approaching those often used for small sewers. A house drain has an occasional rush through it, varied by periods in which there is no flow at all, and, to secure satisfactory working, it is necessary to provide a gradient much greater than what would be calculated for a constantly running pipe. But in a country district, where, perhaps, a sewer of considerable length serves only for a few houses, the same conditions of use are present; but the gradient is calculated very often as for a half-full flow. The case, indeed, is worse than in a house drain, for while in the drain, especially with the modern styles of closets, water is occasionally sent through in considerable bulk, and with momentum due to the vertical descent, the flow before it reaches the sewer becomes less concentrated, and the momentum is spent. In fact, with whatever body and force the water reaches the main intercepting trap, the sudden turn there is sufficient to destroy the last appearance of rush. The result is that the suspended sewage matters are apt to become deposited, and while the liquid may pass along with fair velocity, the solids, if not hopelessly stranded, are leisurely lurching along towards their destination by each successive flow of water that passes. In such a case, even if there is no actual stoppage, the sewage matter may take a much longer time on the journey than would be given by the theoretical velocity—long enough, in fact, to putrefy and to cause great unpleasantness. The odours so produced are, no doubt, much more unpleasant than dangerous, but a proper system of sewerage should not only be free from danger, but should inspire confidence, and for this, if for no other reason, the existence of any odour which will direct public attention to the sewers is a serious evil. If the sewers are ventilated in the most common fashion, by gratings at the road surface, the primary result is an agitation to have the gratings closed, to do which, of course, would merely intensify the evil. The smells are really the outward signs of a disordered system of drains, and it is the removal of the cause, and not of the symptoms, that should occupy the

attention of those in charge. Closing of ventilators leads to the concentration of the contained gases, and probably to their escape in more dangerous places. In any case, I believe that in a small town the sewers can be, and should be, so laid and managed that the ordinary ventilators, placed with some discrimination, will not be objectionable.

To effect this, however, in the case of slightly used sewers, the gradients should be similar to those used in house drainage. If that cannot be done, special flushing may be very desirable. There are, of course, objections to this remedy, sufficiently weighty to make it only a last resort, but, as a last resort, it may have to be used; and it is certainly better in such a case to include the flushing in the original plan, rather than have it forced on after the whole system, perhaps, has been discredited by complaints of smell. There are three special objections to flushing. It uses water which, when most required, may be none too plentiful; it adds to the volume of sewage, and increases the difficulty of disposal; and it requires attention either to work non-automatic appliances or to see that automatic ones are kept in order. It must, however, be remembered that the effect of a flush does not depend merely on the quantity of water used, that momentum depends on velocity as well as on mass, and that a compact body of water, suddenly set free, has more flushing power than ten times the quantity if allowed to dribble off. It would mostly be in dry weather that flushing would be required, and, therefore, the addition to the volume of sewage would be less serious, and although at the same time there would then be the greatest scarcity of water, it might, in many cases, be possible to use for sewer flushing, not the ordinary domestic supply, but some other of less purity and scarcity. Flushing may, at all events, be regarded as a plan which, in special cases, may be of considerable value.

Assuming, however, that we have done everything in our power to keep the sewers clean, the certainty remains that gases will be generated which we have to dispose of. The question of sewer ventilation is one that we must face. We may argue that, in these circumstances, the gases are not sewer gases in the extreme sense of the word, but they are still gases which have been in contact with sewage, and which the public generally, with good cause, look on with great suspicion. The attempt to bottle up these gases will not do. They are certain to escape, and the only

question is whether they will escape by ways of our choosing or of their own. It is, therefore, recognised by every one that we must provide means for the ventilation of the sewers; but, although many different systems have been tried, no plan has yet been devised which will do this with thorough efficiency and without objection. Ventilation by means of private rain-pipes and soil-pipes is recommended by some, but condemned by most on the ground that it allows sewer gas to come much too near our dwellings; ventilation by means of occasional shafts of considerable height is expensive and doubtful; the same objection applies to furnace ventilators; charcoal trays are troublesome, and may readily become ineffective; ventilation by untrapped gullies, or by gratings in the middle of the road, is objected to on the ground of escaping smells; and while the last mentioned plan, gratings in the middle of the road, is the one usually adopted, it cannot be denied that sometimes the objections are well founded. It is impossible to lay down any hard and fast rule as to ventilation, further than to say that, having, in the first place, done our best to make the ventilators unobjectionable, we must also place them in such positions as will cause least annoyance, if, by any chance, smells do escape from them. The difficulty of ventilation will serve, at least, one useful end, if it impresses on us the necessity of so constructing and managing our sewers that smells in them, and, therefore, that smells escaping from them, will be reduced to a minimum.

But, assuming that we have satisfactorily disposed of these and other difficulties regarding the conveyance of sewage, we have still to attack the companion problem of its disposal, and this, in all probability, will be found more full of perplexity and difficulty than the other. The operations of nature run in cycles, and, under natural conditions, the substances which go to form sewage would be returned directly to the earth, there to form a valuable fertilising agent. But when a number of people are collected on a small space of ground, the production of these substances is too great for the ground to utilise, and so, in place of being dealt with in detail, sewage has to be dealt with in bulk. The result is, that in every populous place a large volume of sewage is produced—this sewage consisting of water containing a quantity of suspended matter and a quantity of dissolved matter. These substances, when not actually putrefying, are, at all events, in a state approaching putrefaction, and are more or less offensive

Besides the impurities which a chemist can detect, we may have, and must always assume that we have in any given specimen of sewage, the germs of specific disease. The definition of dirt, "matter in the wrong place," is, of all things, true of sewage. Its constituents could be applied to the ground, not only without harm, but with great advantage; and the mixture of this valuable manure with the water produces a most dangerous and worthless substance. If the two could be separated both would be valuable, but it is in the separation that the difficulty lies. When the question of sewage disposal first became urgent, the manurial value of sewage matters was fully realised, and great fortunes were looked for by individuals, and great profits by communities, in utilising this waste product. After many costly experiments, most of them more or less failures, the dream of boundless wealth to be derived from sewage was slowly abandoned, and those towns which could solve the difficulty by the simple means of running the sewage into the sea came to be envied, as being able, at least, to dispose of their sewage without loss. In other cases, given the sewage, we may do one of two things with it. We may purify it thoroughly, or we may purify it partially. In the former case it will be costly; in the latter, with favourable conditions, it may be profitable. It is an easy matter to take some of the pollution out of the water, but the difficulty increases as the proportion to be removed increases. It is not the first, but the last, step that costs. If the purification must be pushed to a degree at which the effluent water may be considered harmless, the financial result will most probably be on the wrong side. Certain places, no doubt, with exceptionally favourable circumstances and careful management, may be able to show a balance of profit, but the margin is an extremely narrow one, and has a strong tendency to convert itself into a loss.

Where purification is a secondary matter, and profit the first, there is no doubt that profit can be realised, as in the well-known example of the Craigentenny Meadows, where very inferior land, drenched with sewage, produces immense crops; but few towns are in that happy position, and it is with the cases where purification comes first that we are chiefly concerned.

The first stumbling-block in the way of sewage purification is the difficulty of convincing the popular mind that apparent and real purification are two different things. I know that by referring to the difference between precipitation and purification, I am

laying myself open to the charge of repeating elementary information ; but so many cases are constantly occurring where this distinction, if not unknown, is at least ignored, that it is not altogether unnecessary to repeat that sewage from which the suspended matters have been removed by precipitation still contains much of the most valuable manurial matter, or, from the other point of view, much of the most offensive sewage matter. It is, however, such an obvious improvement, as regards appearance, to have the suspended matters removed, that it is extremely difficult to convince people that the purification is incomplete, especially when financial considerations come in to support the incomplete system. When the effluent is to be discharged into a tidal river, or is of small volume compared with the stream into which it runs, this rough purification may sometimes be tolerated ; but in most cases the risk of interdict is not inconsiderable, and, therefore, more efficient means must be adopted. At present the system most suited for any small inland town seems to be filtration in some form or other, either through land or special filters. Precipitation is valuable, not as a substitute, but as a preliminary, sewage being thus roughly purified before it passes on to the filters ; and by a combination of the two an effluent may be secured which, for all practical purposes, may be regarded as pure, and which may be safely run into any stream. The prospect of making a profit had better be ignored. I had hoped to give some figures, resulting from experience, as to the financial results of different methods of purification, but the difficulty in doing so in such a way as to be of any value lies in the fact that the results depend on data which are extremely variable. The expense side of the account consists of items readily compared, such as cost of land, works, and management ; but the credit side, with such items as rental received for sewage, sale of sewage crops and of sewage manure, is extremely unreliable as a guide, for these values vary not only from place to place, but from time to time. Sewage sludge, for instance, has at some times commanded a considerable price, while the same sludge at the same place has at other times been declined as a gift—the tendency of prices being usually downward. In these circumstances, then, it would be of little value to detail figures which might be rather misleading than otherwise.

The plan which, according to usual experience, comes nearest to squaring accounts, if it does not even yield a profit, is that of

irrigation over a considerable area. By this means the manurial value of the sewage is transferred to the land, and then absorbed by the crops. The chief difficulty with this, as with any other system of applying sewage to crops, is that at the time when the crops least require irrigation—that is, in wet weather—there is the greatest volume of sewage, and this must all be passed through the land in order to be purified. The admirable economic results obtained at Craigentinny are due to the possibility of ignoring this requirement, and allowing the sewage to flow past when it is not wanted. The larger the area, on the other hand, the greater the risk of nuisance.

As regards purification, the essential point is that the sewage must pass through the soil, and that the soil should not be continuously saturated with it. We occasionally come across cases where sewage is allowed to run on to the surface of water-logged land, in the expectation that its manurial elements will be extracted by the surface growths. It has, however, been again and again proved that sewage which merely runs over land is not purified entirely by the growing plants. Our reliance for thorough purification is not the absorptive power of the plants, but the oxidising action of the soil. The plants are added as a means of utilising as far as possible the valuable portions of the sewage, but the ground itself is the final reliance. The difference between irrigation and land filtration is very much one of degree. The area, in the case of irrigation, is decided by considerations of how best to grow profitable crops; the area, in the case of filtration, is decided on the basis of how little will effectually purify the sewage. Good crops are aimed at in the one case, economy of land in the other. In the latter case, the land is really laid out as a large filter; and although crops are usually grown on its surface, the purpose is merely to make what use can be made of the matters which the filter would otherwise burn. The ground is prepared and underdrained to a depth of six or seven feet, and each part is used only intermittently. Both of these plans—irrigation and filtration—can be carried out so as to produce an effluent not only apparently but actually harmless, and from their comparative simplicity will probably be the solution of the difficulty adopted in many cases. In those cases where land is too limited even for the adoption of land filtration—"intermittent downward filtration," as it is technically called—some system of chemical treatment may have to be adopted. The number of

these systems is enormous, and it would be tedious even to enumerate them. The most prominent just now is probably that known as the International system, in which, by a combination of precipitation and filtration, a very good effluent is produced. I had occasion recently to visit more than one place where this system was in operation, and, to all appearance, with great success.

The smaller the area occupied by the works, the less chance there is of nuisance being produced ; but any of the systems to which I have referred can be carried out with reasonable freedom from offence. A sewage farm, of course, is not exactly the place to lay off as a pleasure ground, any more than a field to which guano is being applied would be. With reference to all these systems, it may be remarked that their proper working almost certainly depends on the exclusion of rain water ; and it may now be taken as an axiom that, in a rural district, where sewage has to be treated in any way before discharge, rain water should not to any extent enter the sewer. The smaller the area of land available for purification, the more important it becomes to keep down the quantity of sewage.

In the case of a community on a hillside, with a considerable amount of suitable ground at a lower level, the sewage will be readily disposed of by irrigation ; but where irrigation would imply any handling of the sewage, such as pumping, then it is undoubtedly best to adopt a more compact method of purification, if by that means pumping can be saved. The increased results from broad irrigation will not repay the cost of pumping. Those communities are in the worst position where pumping is necessary as a preliminary to any method of purification.

Reviewing the situation generally, it may be said that difficulties as regards sewerage must apparently be met in the future by the means already at our command, which are in most cases quite sufficient. As regards sewage disposal, on the other hand, while the means we already have can be made to serve the purpose, for such places as we are considering, with considerable efficiency, it is not impossible, perhaps not even improbable, that scientific researches may yet provide us with some means whereby sewage may become a valuable, in place of a very troublesome, possession. In the meantime, however, public opinion is becoming more and more decided against the pollution of streams, and many places cannot afford to wait for new discoveries, but must make the best they can of those which are already available.

VI.—*Women's Wages*. By WILLIAM SMART, M.A., Lecturer on  
Political Economy in Queen Margaret College.

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[Read before the Society, 9th December, 1891.]

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It is not necessary to prove that women's wages are, as a rule, much under those of men. In the textile trades of Great Britain, which constitute the largest department of women's work, the average of women's wages is probably—in Scotland it is certainly—about ten shillings per week. This labour is not by any means unskilled, as anyone who has ever seen a spinning or weaving factory knows. Twenty shillings per week, however, is a low average for a man possessing any degree of skill whatever.

In a paper read before the British Association at Cardiff, Mr. Sidney Webb gave some valuable statistics on the subject. Women workers he divides into four classes—manual labourers, routine mental workers, artistic workers, and intellectual workers. The two latter classes may be dismissed in a word. Sex has little to do in determining the wages of their work. A novelist, a poet, a writer of any sort, is under no disadvantage that she is a woman, while in many departments of artistic work women have an obvious advantage. But in the third class, that of routine mental workers, Mr. Webb finds that women's earnings are invariably less than men's. In the Post Office and Telegraph Departments, in the Savings Banks, and in the Government offices generally, where women do precisely similar work with men, and are sometimes, as in ledger work, acknowledged to do it better, they invariably earn much less. The largest experiment yet made in this direction is that of the Prudential Life Assurance Office, which began in 1872 to substitute women clerks for the lower grades of men clerks. There are now 243 ladies employed in routine clerical work, which they are said to do more efficiently than men. The salaries run thus:—£32 for the first year, £42 for the second, £52 for the third, and £60

on promotion—probably half of what men might be expected to accept. In Glasgow lady typists and shorthand writers are offering their services from 9.30 till 5, with one hour for dinner, for £25. In the teaching profession women almost invariably receive lower remuneration than men. The Education Department Report of 1888-90 gives the average wage of teachers throughout England and Wales as £119 for men and £75 for women. Similarly low salaries are found under the London School Board, in the Secondary Schools, and in girls' schools generally as compared with boys' schools.

The exception noted by Mr. Webb is interesting and, I think, suggestive. In the United States, where women teachers often alternate with men in the same school, the salaries of women are habitually lower. But in the State of Wyoming, where women have a vote, the salaries are equal.

Coming now to the manual workers, Mr. Webb takes the statistics furnished by the Massachusetts Bureau of Statistics of Labour in 1884. These give the average of 17,430 employes in 110 establishments in Great Britain, and 35,902 employes in 210 establishments in Massachusetts, representing in both cases 24 different manufacturing industries. The women's wages show a proportion of one-third to two-thirds the amount earned by men, the nearest approach to equality being in textiles—cotton goods, hosiery, and carpetings in Great Britain, woollen and worsted goods in Massachusetts. Without going further into statistics, I think we may assume the fact of a great disparity between men's and women's wages, and go on to ask the reason of it.

If we put the question in general terms, Why is a woman's wage less than that of a man? there are some answers that spring to the lips of everyone. First, it is said that it is a mere question of supply and demand; second, that women are not usually the sole bread-winners in the family to which they belong; third, that their standard of living is lower than that of men; fourth, that their work is not so good as that of men; and, fifth, that the commodities made by women have, generally, a less value in the market. There is truth in all these answers, but I propose to show that each of them is at best a half truth, raising as many questions as it settles.

The first answer given is that women's wages are low because of the equation of supply and demand. Only certain branches of industry are open to women. In these there is a great

number of women competing for employment. They are free to take work or refuse it. But over the industrial community there are found enough women willing to take the low wage which employers find they can offer, and free competition determines the level. If two women run after one employer, wages will fall; if two employers run after one woman, wages will rise.

Those who think this answer an easy and satisfactory one must be unaware of the unsettling of many problems since Mill's day. Mill had no less than three laws of value—that of the Equation of Supply and Demand, that of Cost of Production, and that of Differential Cost of Production. The former law, he said, applied to goods of which the quantity was naturally, or artificially, or temporarily, limited, and it was, besides, the sole determinant of the value of labour. But then Mill was assuming a definite Wage Fund—a fixed portion of the circulating capital of the country predestined for the payment of wages. This definite sum, and no more, was to employ all the workers, however numerous they might be. If, then, wages fell, the reason was obvious—there were too many workers. Wherever Mill touches on low wages we have a sermon on the evils of over-population, and his favourite explanation did not fail him here. "Where employers take full advantage of competition, the low wages of women are a proof that the employments are overstocked." But this is logical only if "overstocking" is the sole possible cause of low wages—which might be doubted even under a Wage Fund theory. But the Wage Fund is now one of the antiquities of political economy. Since Jevons we have looked for the measure of value in marginal utility; for the value of productive goods in their marginal utility as instruments of production; and for the value of labour in the value of its products, and not in any predetermined fund divided out among a variable number of workers by the action of supply and demand. And where invention is constantly widening and strengthening our power over natural resources and increasing the productiveness of labour, the presumption is against the idea that over-population is even a strong factor in modern wages.

There is, indeed, no formula in political economy on which the modern economist looks with more suspicion than that of Supply and Demand. The operation of supply and demand as determining market price is, of course, perfectly definite; but to say that any concrete price is fixed by the equation of supply and

demand is a mere statement of an observed fact which says little, unless one knows and defines accurately what is involved in the "supply," what is involved in the "demand," and how those two factors stand related to each other. The price of railway stock to-day is determined by supply and demand; the price of a man's labour, whether unattached or working under restriction of the Trade Union, is determined by supply and demand; the earnings of the poor soul who sells her body on the streets are determined by supply and demand. What does this formula tell us unless we know the complex phenomena which determine the supply of railways and the demand for transit, the supply of labourers and the demand for work, the supply of hapless women and the demand for human souls? To say, then, that women's wages are low because there are enough women who take the low wage, is little more than to say that wages are low because people are paid low wages. We have still to ask: What are the factors, or influences, or motives, that make women take a wage below that of men, and what are the factors that make employers offer the low wage?

Apart from the general insufficiency of this first answer, it is enough to remember that the determination of wage by this mechanical equation of supply and demand could be tolerable only under absolutely free competition, which would involve perfect mobility of labour. But labour has this unique characteristic among all commodities that, physically, it is not mobile; historically, it has never been mobile; and ethically, it should not be mobile. A man's labour is—and should be—his life, not the mere instrument of providing a living; and, therefore, in the question of wages it is impossible to ignore the ethical consideration. Civilised society could not hold together if the workman and workwoman could only get their fair share of the world's boundless wealth by changing their trade, their residence, or their country, as a higher wage offered itself.

The second reason given is that, women not being as a rule the sole bread-winners of the family, their wage is auxiliary to that of its head; the woman's wage is, as it were, "found" money in the household purse. Underlying this statement is an assumption which is at least questionable. It is that the economic or wage-earning unit is the *family*. This is an old-time idea which, however beautiful and desirable, is a little out of place in the conditions to which the factory system has brought us. Once-a-day

it was recognised that children had a far greater claim on the persons who brought them into the world than we now allow. It was thought that the one wage should be earned by the head of the house, and should be large enough to maintain the wife and daughters without outside work, and to educate and apprentice the sons till they were able to hive off for themselves. Any money earned by the junior members of the family was, in this case, supplementary, and determined by a different law. Perhaps in time we may come back to this view. Mr. Frederic Harrison is sanguine that we shall. But meantime the factory system has changed all that, and it is scarcely worth while looking for laws of wage in a condition of family life which does not now obtain. Putting aside the objections that many married women are not members of a family, and that many married women and widows are the sole bread-winners of the family, it is perhaps sufficient to point out that this answer would not be taken as explaining or justifying a low wage among what we call the "better classes." It would not be counted an excuse or reason for a publisher asking a lady novelist to accept a lower price for her books, or for a patient offering a lower fee to a lady doctor. If the sex of the author, artist, musician, doctor, intellectual or artistic worker generally, has nothing to do with her remuneration, why should sex determine the wage of the factory girl?

More clearly does this objection emerge when we consider the third answer. It is said that the inferiority of women's wage is owing to their standard of living being less than that of men. It is true that a woman, as a rule, eats less, drinks less, and smokes less. Tea to her is, unfortunately, both meat and drink, and it would be counted extravagance in a working woman if she took to eating twopence worth of sweets a day as balancing the man's half ounce of tobacco. But I am afraid a woman's standard of life differs from a man's rather in its items than in its cost. I have yet to learn that her standard of dress is less than ours, and I am quite sure she takes more medicines, and spends more on doctors' bills. As in the former case, we change our view according as we look at different classes. Among the "upper" classes, as we call them, the woman's standard of life is very much higher than that of the man. It is only because the poor seamstress, when put to it, will live on a shilling a-day, while a man will become a tramp or go to the workhouse first, that we say the woman requires less.

In a word, it is not that the physical and mental needs of woman are less than the physical and mental needs of man, but that many women, for some reason or other, can be got to accept a wage that will only keep them alive. If so, the answer, translated, simply runs: Women's wages are less than men's because, for some reason, women accept less.

It is to be noted, however, as very significant of the popular ideas about wage, that the second and third answers just given account for the standard of women's wages by the *wants* of the worker. A woman's wage is low because she does not *require* a high wage, whether it be because her father partly supports her, or because her maintenance does not require so much. Now it may be said in passing that it is quite against our modern ideas to represent wage as regulated by wants. Under a socialistic régime, indeed, the wages of all might be thrown into a common purse, and divided out according to the wants and necessities of each; but under an individualist régime, like the present, what the worker *is* is nothing, what the worker *does* is everything. To assess the value of goods by the cost to the human life which makes them is to take ground on which the world is not prepared to follow the economist whatever it may say to the moralist. It is not the cost in killed and wounded that decides the battle. To the purchaser it is indifferent whether the cloth he buys wore out the fingers and heart of a woman, or only took a little tear and wear out of a machine. The one question he asks is: How will the cloth wear? *Caveat venditor*. If a man-worker, then, is supposed to get a high wage when he produces much, a low wage when he produces little, why should a woman's wage be determined by another principle? We cannot hunt with the individualist hounds and run with the socialist hare.

The next two reasons, accordingly, put the low wages of women on quite different and more scientific ground—namely, that of the work they produce. Of these the fourth says that women's work is not so good as men's. As a statement of fact this is probably true. It is no disparagement to the sex to acknowledge that, if women are necessarily off work several days in the year because of little ailments common to them, if they are insufficiently nourished relatively to their needs, or are naturally more delicate than men, their wage at the week's end will be less than that paid to the average man who scarcely knows what a headache means. Or, if the woman is compelled by law to leave the factory

at six, while the man can stay and work overtime ; or, if she is driven to the street for an hour at meal-time, while the man can gulp his tea within the walls and get back to his work half-an-hour earlier ; we can see that the wage of the man will be higher by the time and the overtime he works. Similarly, if it requires not only skill but strength to work a heavy loom ; or, if a man can do two jobs, the one alternative to the other ; or, if he can "set" and "point" his tools as well as work his machine, while a woman has to go to the mechanic's shop for these things ; in cases like these—and they are, of course, very many—we require no answer to our question. It is simply a case of better wages for better work—better in quantity, or in quality, or, at least, in advantage to the employer. That is to say, if men and women are working side by side at the same trades, and under similar conditions, it requires little explanation to say why the wages of men should be 20s. and the wages of women, say, 15s.

If this were all, the inferiority of women's wage would not be primarily a question of sex at all ; it would be very much a question of unskilled labour as compared with skilled labour. Women would get lower wages than men for the same reason as the dock labourer gets lower wages than the artisan, and the artisan than the physician. The world might suffer nothing in pocket by adopting the principle—which, however, I am afraid is yet far from general acceptance—of Equal Wages for Equal Work, whatever the sex of the worker. And here it is that Mr. Sydney Webb deserves thanks for having accented a fact which we all indeed knew, but of which few of us saw the bearing. It is that men and women do not, as a rule, produce similar work alongside of each other, and that any argument which compares the wages of both sexes, without taking account of this fact, quite misses the mark.

To recur to the facts adduced by Mr. Webb : it seems to be impossible, he says, to discover any but a few instances in which men and women do precisely similar work in the same place and at the same epoch. In the tailoring trade, for instance, men do one class of garment, women another. In the cigar trade women make the lower-priced goods. So is it in all the Birmingham trades. In paper mills men do the heavier, women the lighter work. In cotton spinning, the mule tenders, called, *par excellence*, "spinners," are men, while women take all the preparatory processes. But there is one exceptional trade where this does not

hold. "Weaving," says Mr. Webb, "appears to be nearly always paid at equal rates to men and women, whatever the material or locality." This seems to hold as regards the weaving industry generally, from the hand-loom weavers of Ireland to the carpet weavers of our own country; and it extends also to other countries, as, for instance, to the cotton and silk weaving in France. That is to say, as I understand, that the piece-work rate is the same, although in special cases strength may give the man an advantage in handling heavy looms. But what is most remarkable is that, over the great weaving district of Lancashire, not only are the rates of piece-work the same, but men and women do exactly the same work side by side in the same sheds, practically under the same Factory Act restrictions, and earn equal wages, namely, an average from 17s. 11d. in Carlisle to 21s. 4d. in Burnley. This, however, is distinctly and notably an exception. Women compositors, for instance, in London, receive uniformly lower piece-work rates for exactly similar work; for the same work the union man gets 8½d., the non-union man 7½d., and the woman only 5½d. As an exception, however, we shall have reason to recur to the Lancashire weavers later.

We thus come naturally to the fifth answer given to our question. It points to the fact that the kind of commodities made by women, or in women's trades, have, generally, a less value in the market—they are "cheap" goods. Even as a mere statement of fact this proposition is very loose. What are cheap goods? In the absence of any absolute standard of value, goods can be called cheap only as comparing present prices with prices of similar goods in the past, or in consideration of their cost of production as compared with other goods. If the former is meant, all modern manufactured goods are cheap, and this would not explain the lower wage of one sex. If the latter, it is prejudging the whole question. But to make this statement an explanation, and suggest that cheap prices are the cause of low wages, is surely to turn the causal connection the wrong way about; for the value of goods such as we are speaking of depends, according to the recognised theory, on cost of production, and of this cost of production wages is a large part. It is true that the connection between prices and wages is one on which economic science is somewhat slow to speak. We may not now be so confident as Mill was when he put the proposition "high prices make high wages" among common erroneous notions. And we may not be

prepared to say with him that the effect of prices on wages is only indirect, through increased profits adding to capital. But we are not prepared, I think, to go in face of all our old faith, and declare that the *prices* of goods determine their cost of production!

But as a fallacy is not usually put in a bald form, we must consider the concrete case in which it is assumed. Let us take an industry—say a branch of the textile trade—where labour constitutes a great part of the costs of production. Suppose that for many years low prices have ruled for the particular class of goods made. Any attempt to raise wages here meets with an obvious criticism. It seems most plausible to say: It is the wants of the people which have established this demand. The present price is all the consumers can or will pay, and the low wage is all that these prices can afford.

This is probably quite true. Once the prices are down, it is difficult to see how wages can be higher. But what brought down the prices? Is it ever the case that the world of consumers, practically, go to the workers and ask them to accept low wages on the ground that they can only afford low prices? Experience does not bear this out. So far as I know, the initiative of reducing prices, as a rule, comes from the producers, not from the public. The history of prices of most commodities of large use is something like this. They are at first dear, and only a small circle of consumers can afford them. As the production becomes organised, and capital brings more and more appliances to bear on the manufacture, the goods become cheaper, and a wider circle of demand is found. But below each circle of actual demand there are endless and widening circles of potential demand ready to take any particular commodity if it can be had cheaper. Thus, as, up to a certain point, large production is cheap production, there is always an inducement to the manufacturer and merchant to produce more cheaply. If they can reduce prices, and get down to a lower circle of consumers, it is well known in practical experience that the increase of trade which follows is out of all proportion to the degree of the reduction of price. But when this movement has gone on for some time, and goods have become very cheap, the demand has a way of appearing imperative, especially if these goods have entered into the standard of comfort of great classes. The goods become “necessary;” the low prices meet a

"natural" demand; and these prices are just enough to yield an average profit to the employer—for profit must have its average, or capital, as we are often warned, will fly the country.

This is all quite true. The fallacy emerges only when it is suggested that the low prices are the cause of low wages. Here there are two possibilities: (1) All the reduction of cost may have been effected by perfecting machinery, organising production, and bringing producer and consumer together—that is to say, all the cheapening may have come from the side of capital. In this case there is no room for laying low wages at the door of cheapened prices. Or (2) as wages constitute one of the chief costs in all production—in the United States, for instance, they make up on an average a quarter of the manufacturing cost—they may have been reduced along with the capital expenses, and the low prices be partly due to these low wages.

What this does prove is, of course, that it was the reduction of wages, among other things, that made the reduction of prices possible. But what it was proposed to prove was the converse proposition, that the low prices made the low wages! To put it, then, in the plausible way, that the reduced prices "do not allow" of higher wages, is simply a very pretty specimen of the argument known to the vulgar as "putting the cart before the horse." What, however, we may very well learn from the wide acceptance of this view is that it is a very difficult thing to raise wages once they are down; and it may suggest that employers have some responsibility in reducing, and the public some responsibility in giving excuse for them being reduced.

Thus we seem to be still without an adequate answer to the question: Why is a woman's wage less than that of a man? But the last answer, unsatisfactory as it is in itself, seems to me to have a value in something further that it suggests. It seems to draw attention to a notable fact, and to point the way to a new formulation of the whole question. The fact is this, that women are in almost exclusive possession of certain branches of trade, and that, in these branches, the commodities made are recognised by public opinion as being "cheap." The observation of most of us must confirm Mr. Webb's conclusion, that there are certain trades where men do not compete with women; indeed, that there is a well marked relegation of women-workers towards certain ill-paid trades; while, at the same time, there is as well marked a movement of men towards the better-paid trades. If this is so, the

difference of wages between men and women takes a new and definite aspect. It is not a difference of wage between workers of various degrees of efficiency. It is very much a question of difference of wage between two non-competing groups, and of groups where the levels of wage are determined by a different law. The question is not: Why are men and women employed in equal work at unequal wages? but, Why are men and women employed in different groups of employment? and, comparing these two groups, Why is the wage-level of skilled female labour lower even than that of unskilled male labour?

The reasons may be found in observing a course of events constantly under our eyes. There are always certain trades where women are still competing more or less directly with men. In these, women are under certain disabilities of sex which make their work less remunerative or less profitable to their employers. They are, as I said, physically weaker; subject to little ailments which make them less regular in attendance; more liable to distraction of purpose; perhaps worse educated; and, probably, more slipshod in their methods. They get less wages because, either in quantity or quality or both, their work is not so good. This competition of the women tends to drag down wages for both sexes, and, as a consequence, men hive off to trades where there is more opportunity, or retain certain better-paid branches within trades, and certain trades or branches of trades are left to women. Whenever this is the case the women lose the advantage of competing with workers who will not accept wages under a certain level. Their disabilities, thus become cumulative, are taken advantage of by unthinking or unscrupulous employers, and all other employers are forced to follow.

If tailors and tailoresses are working side by side making coats and vests indifferently, it is not difficult to understand why the men may earn 20s. to the women's 15s. But if, in time, the men get all the coats, and the women all the vests, we have a good reason why the women's wage goes down to 10s., while the men's remains at 20s.

Or equally common is another course of events. A certain industry, we shall suppose, has been worked exclusively by men. By a "happy" invention machinery is introduced which can be tended perfectly well by women. For a little time the dead weight of custom will probably retain men to tend these machines, and the wage will certainly not fall below the average wage of

men generally, which we shall, for simplicity's sake, put down at 20s. But, either gradually or as result perhaps of a dispute or strike on the part of the men, women are introduced to tend the machines. Does their pay bear any proportion to that of the men they replace? It is quite certain that the women's remuneration will not be determined by the 20s. wage which they displace, but will be fixed at something like 10s. If we ask why, the only answer given is that 10s. is the "customary wage" for women.

People who have no practical experience are apt to think that economists are theorising in speaking of "customary" wage. It will be said that the steady replacing of hand labour by machinery, and of old machines by improved machines, breaks up the continuity of wages, and weakens the element of custom. A simple illustration from a trade I know very well will show how far this is true. In the cotton thread trade, spooling—that is to say, winding the thread on the small bobbin familiar to every work-basket—was for many years done by women sitting at single machines not unlike sewing machines, filling one spool at a time. The customary wage was sixpence per gross of 200-yard spools; a good worker could spool at least four gross per day, and make twelve shillings a week. As in all industries, machinery was gradually introduced by which cunning arrangements of mechanism did the greater part of the work; instead of turning out one spool at a time the girl now watched the machine turning out six, or nine, or twelve spools. When these machines were introduced, how were the wages determined? For a few weeks the girls were put on day wages, and when the machines were in good working order, and the average production per machine had been ascertained, the piece-work rate was fixed so as to allow of the girl making the same average wage as she did before. That is to say, if the new machine turned out in the same time six gross for every one gross turned out by the hand machine, the price of labour per gross was reduced from sixpence to one penny, and the wage continued at the customary level. So far as sacrifice or skill goes, there was no reason why the worker should get more, as, on the whole, it required less skill and attention to turn out the six gross than it did to turn out the one. Thus it is, I believe, over all the textile manufactures, with the exception, perhaps, of weaving. The introduction of new processes displaces labour, but the labour left does not get higher wages.

This, then, is the first conclusion I would come to: that in more cases than we would believe the wage of women-workers is a "customary wage," fixed at a time when the world was poorer, and capital was more powerful.

This conclusion is, I think, strengthened by the case which, at first sight, would seem to refute it. The great outstanding exception to low wages in women's industries is, as before noted, in the Lancashire weaving.

There, not only are the rates of piece-work the same, but men and women do exactly the same work side by side, practically under the same Factory Act restrictions, and earn equal wages, namely, an average of from 17s. 1d. in Carlisle to 21s. 4d. in Burnley.

But there is an exceptional circumstance in their case. It is that the women are in the same strong Trade Union with the men, and under the same obligations to the Union, and that any attempt to reduce the wages of the one sex would be resisted with the whole strength of both. But what if this Union were to break down?

It is as certain as anything based on experience can be that in a few weeks, or even days, it would be possible for the employers to reduce the wages of the women-workers; that, rather than lose their work, women would consent to the reduction; that, as they accepted lower wages, men would drop off to other industries, and would cease to compete for the same work; and that, in a comparatively short time, power-loom weaving would be left, like its sister cotton-spinning, to women-workers exclusively, and wages fall to the general level of women's wage. For what we are apt to forget is the constant inducement before the employer to reduce women's wages. There are two ways in which a manufacturer can add to his profits. One is by getting up his prices, the other by reducing his costs. In the present state of competition we know what the chance of getting up prices is, unless there is some element of monopoly in the case, and even then it generally requires a combination or syndicate of makers. But the employer is always looking out for ways of reducing cost. Theoretically, the most obvious way of all is by reducing wages. In men's trades, where reductions of wage are jealously watched, employers think twice, however, before they try that particular reduction of cost. In many factories, again, women's wages are purely customary, and

employers would not think of touching them. But in the factories where wages are customary and almost fixed, the wages are also low. If the customary wages in cotton-spinning were 16s. a week instead of 10s., I venture to think that employers, in times of keen competition, would be inclined to try a reduction. I mean that, if the customary level of women's wages is 10s., the reason why it does not go lower is chiefly because it cannot.

And here, I think, we are at the root of the matter. In looking over the field of factory industries, in order to arrive at an average of women's wages, it has struck me that the variations from the average of 10s. a week are comparatively small. This is not an average made up from widely different wage-bills, and from widely varying individual wages, but from pay-sheets that show small amounts of variation on one side or other.

This definiteness of average wage seems to me most explicable on the supposition that women's wages are very near the only quite definite level that political economy has ever pointed out, the level of subsistence.

There are two ways, known to theory, of determining wage. In a progressive society, where wealth is rapidly increasing, the tendency will be towards payments by *results*, that is to say, by value of product. Product being in this case the result of the co-operation of land, labour, and capital, the problem is to find the share in that product which is economically due to labour—that is to say, the share “attributable” to the efficacy of labour. In a poor or backward society, again, where labour and capital are struggling with an unfriendly environment, and the return to industry is still uncertain, the risk and the chances of speculation in the return are left to the only class who can take risks—the capitalists.

England long ago passed from the latter to the former description of society, and of her increased wealth the men-workers have obtained, we may suppose, something like a share corresponding to the increased value of the joint product. But, owing to want of organisation of women-workers, it is yet possible to pay women by the other standard—namely, according to their *wants*—and to keep them at the same level of wage as they were content to take half-a-century ago.

It seems to me, in fact, that while men's wages, unless in the case of unskilled workers, are determined ultimately by the value of product which is economically “attributable” to their work,

women's wages are determined by the older and harsher law. "The wages, at least of single women," said Mill, "must be equal to their support, but need not be more than equal to it; the minimum in their case is the pittance absolutely required for the sustenance of one human being. . . . The *ne plus ultra* of low wages, therefore (except during some transitory crisis, or in some decaying employment), can hardly occur in any occupation which the person employed has to live by, except the occupations of women."

But, indeed, it is a lower depth to which women's wages have fallen than the "sustenance of one human being." There may be persons that think 10s. a week is sufficient to keep a grown-up factory girl, living by herself, in healthy and decent life. It certainly is true that in many cases it has to serve till she accepts the release of marriage; but surely the marriage of the English girl, factory or otherwise, is a matter too serious to have the escape from a miserable wage added to its attractions. It is sufficiently obvious that this level of wage was never determined by sustenance, but by the competition of the "single woman" with married women and widows, who will take any wage rather than see their children starve, with girls sent into the factory to add their few pence per week to the earnings of the head of the house, and with children.

If this is so, what are the remedies? They are, briefly, organisation and enlightenment of the public conscience.

First, organisation is necessary to protect women against employers and against themselves—the one no less than the other. The true enemies of the workers' organisations are, on the one hand, the grasping employer, and, on the other, the "blackleg" worker. By the grasping employer I mean the employer who really wishes to make a gain at the expense of the people whom he employs; it is easy to see why he dislikes the trade union. But the good employer—if he could only lift his horizon a little—would see that he requires the help of the trade union, inasmuch as he cannot keep up the wages if the workers do not assist him. The best, the most amiable, and just manufacturer must sell his goods at the same prices as his rivals. If these rivals, by securing low-priced labour, can reduce the prices of their goods, he is almost forced to reduce his wages. Consequently, if the trade unions could prevent low-priced labour being offered they would most materially assist the great majority of

employers;—for I am sanguine enough to believe that most employers are anxious to pay their workers as high a wage as they can. But the best employers are helpless to remedy the evils of a class of workers who are hopelessly at war amongst themselves; and ready to take each a lower wage than the other. Where a girl, coming out of a comfortable home, is willing to take 10s. a week because to her it is “pocket money;” where the mother of five will take 8s. because her husband is out of work and she is the sole bread-winner; where the mother of ten will accept 6s. because she has so many mouths to feed; where the girl just in her teens will take 4s. because she is a little girl—where all these different women, with different motives, are competing against each other for equal work, there is no remedy but the severe one of *preventing* these poor souls from dragging down the wage of each other. If women are ever to get a fair day’s wage on the ground of a fair day’s *work*, as distinguished from the wage determined by a woman’s necessity, it will only be by the old remedy of combination and the protection of the average working woman against the more helpless members of her own sex.

But, second, enlightenment of the public conscience must supplement organisation. It should not be difficult to convince educated people that women’s work should be paid on the same principle as that of men—that is to say, according to their product, and not according to their wants; and to make them pay, or insist on the worker being paid, equal wages for equal work. But the point on which enlightenment does seem very much needed is that of the supposed necessity for low wages.

I do not know how there could be any such necessity unless it was the case that labour and capital, like land in some countries, had entered on the stage of decreasing returns, and had, moreover, gone so far on that down grade that the additional returns grew more slowly than population—and no one has even suggested such an idea. I have already tried to point out the fallacy that low prices explain low wages. It is, however, perhaps advisable to note that they do not even, to any great extent, condone, much less justify them.

Probably we are all familiar with an argument like this: Consider, it is said, the great fact that calico is twopence a yard. Every woman in England may now be clad in cotton fabrics which, a century ago, were beyond the purchasing power

of a queen. Beware how women are encouraged to ask and to stand for higher wages, or calico will again be put beyond the reach of any but queens. I confess I never heard this caution without remembering Carlyle's indignant reply:—"We cannot have prosperous cotton trades at the expense of keeping the Devil a partner in them." The weakness of it will become obvious if we carry the matter a little further and argue that if we can succeed in reducing women's wages still more, say, to 5s. per week, we shall have a considerable reduction in the price of calico, and bring the commodity within the reach of still poorer people.

It is Dickens, I think, who speaks of a horse that was fed on a system which would have reduced his cost of upkeep to a straw a day, and would, no doubt, have made him a very rampageous animal at that if, unfortunately, the horse had not died! The idea that cheapness of goods makes up for everything in the workers' circumstances is, perhaps, the most deplorable of current fallacies. It is no less than that of mistaking the whole end and aim of industry. The goal of economic effort is not accumulation of wealth, but the support of wealthy human beings—not "goods," as Aristotle told us long ago, but the "good life." True economical cheapening of production is cheapening of natural powers *outside* of man—not cheap labour, but cheap machinery, cheap organisation, cheap transit. This is a kind of cheapening of product which can go on indefinitely. From the dawn of civilisation man has been turning a hostile or indifferent environment into a rich and friendly one. For ages, indeed, constant war hindered this conquest of nature. It is only in this century that comparative peace among nations has allowed the majority of men to give all their time and thought to the economical life, and even yet the locusts of standing armies eat up great part of our harvest field. But the changes which have been made on the earth, as we know it, the natural resources of matter and force now under our control, the complex and sensitive organisation which knits the world together, all point to possibilities of wealth beyond the wildest dreams of last century. There is some fatal leak in our industrial system if every child in Great Britain this year is not the heir of a richer heritage, at least of richer possibilities, than the child of last year. If our fathers a generation ago earned 20s. by day labouring, we should be earning 40s. by day labouring; or, if we are still earning only 20s., the 20s. now should buy what 40s. bought then.

Now, as this suggests, there are two lines which the economical progress of the workers may take—that of advancing wages or that of cheapening products. Which of these is preferable? Without entering on any more discussion, two considerations may show that there is no comparison between the two, so far as the workers are concerned.

First, the ideal condition of average human life is a condition of well-paid wage-earning ; of steady assured labour, which does not strain or stress, and is crowned visibly by the fruit of its own exertion. There is nothing more depressing to the thoughtful economist than the waste, positive and negative, which comes of disorganised labour ; where the working man and his wage are the sport of speculation, and the period of high wages and overtime is succeeded by periods when the worker is thrown on the streets to learn the bad lesson of spare time without culture, and of leisure without rest. It is of small comfort to the working man that the manufacturer and merchant share the bad time with him, and that stocks are thrown on the market at “ruinous sacrifices.” In vain is the cheap sale advertised in sight of the penniless buyer.

Second, while from one point of view it is all the same whether a worker's wage is raised from 20s. to 40s. a week, or whether everything he buys is reduced by 50 per cent., the balance of advantage is not so simple as this. If the wages are raised the worker alone gets the benefit. If commodities are reduced in price those who consume them—namely, the whole community—get the benefit. If, by reducing Tom's wages, you reduce the price of commodities which Tom, Dick, and Harry buy, Tom divides the economic advantage, such as it is, with Dick and Harry. Thus reduction of wages is never fully compensated by reduction of prices. The seigniorage of current commodities is borne, not by the community but by the workers.

Thus, I repeat that, while the fact that wider circles of population get the advantage of cheap goods is some mitigation of the evil, it is no justification of it. There is no reason why products should reach wider and wider circles, except that the cheap products are a gain to the wider circles. And if this gain tends to be outweighed by the evils of reduced wages, calico at twopence a yard may be too cheap.

But if there is still some question whether, economically, it is justifiable and advisable to organise workers to ask higher wages,

and to educate the public conscience to pay them, it may be settled, as regards women at least, by this simple consideration. Wealth in Great Britain, according to Mr. Giffen, increases annually by 3 per cent., while population increases by only 1·3 per cent. That is to say, wealth increases more than twice as fast as population. In the light of this statistic it cannot be economically necessary that women's remuneration for labour should remain at the subsistence level. If this was a fair wage fifty years ago, it cannot be so now.

VII.—*Progress of School Building in Glasgow from 1873 to 1892.* By JOHN M'MATH, Master of Works, School Board of Glasgow.

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[Read to the Architectural Section, 30th November, 1891.]

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(PLATE II.)

THE subject under consideration this evening has, it will be readily admitted by all present, a most vital relationship to that most memorable year in the educational history of Scotland, 1872—the year of the passing of the Scotch Education Act, a measure whose provisions have been alike far-reaching and potent, and which, in its great comprehensiveness and excellent results, is placing Scotland rapidly, so far as intellectual development is concerned, in the fore-front rank of the nations. It is by no means the province of this paper to discuss the technical or scholastic aspects of the educational administration of our city. We shall, in keeping strictly to the scope of our subject, confine ourselves to a survey of the architectural development of the various educational edifices which have been raised under the administration of the School Board of Glasgow during the eighteen years which have elapsed since the Education Act came into force; and while the development in intellectual force and culture in the time alluded to has been brilliant in the extreme, the progress made with reference to our educational buildings, not only as regards comfort and attention to the laws of health, but also in relation to architectural beauty, has been a feature worthy of the sincerest congratulations.

In placing the features of architectural design and progress before every cultured and unbiased mind present, it must be admitted that these eighteen years have wrought marvels in building development, and that the structures have in many cases outrun our wildest fancies, and look, as they stand there in carved and finished stone, as if they were the modern results of some imaginative creations of the “Arabian Nights.”

When we consider the splendid structures we have now as educational institutions in our city, it is an act alike natural and graceful that we should gratefully recognise the able work performed by the first School Board which Glasgow appointed in 1873, immediately after the Education Act came into force. To the firmly representative character, the strong individuality, and the great administrative power of that Board we owe much in the way of laying down an enlightened yet firm policy, which subsequent Boards have, in a large measure, wisely followed out. It will be remembered that the leading members of that Board were Mr. Alexander Whitelaw, M.P.; Dr. James A. Campbell, M.P.; Sir Michael Connal, Mr. Mitchell, Mr. Long, and Monsignor Munro, with Dr. Kennedy as clerk.\* Happily the latter five gentlemen have been associated with all the succeeding Boards, and by their zeal, integrity, and strong administrative power have been of inestimable value in the cause of education.

In true business-like fashion the first School Board considered it their earliest duty to obtain full and accurate reports on two most important points in order to meet the educational requirements of the city;—firstly, a properly classified list of all the schools then existing in the city; and, secondly, an accurate census of all the children in the city between 5 and 13 years of age.

The various schools then in existence in the city, together with the districts in which they were situated, were classified in the following order:—

- A. Schools inspected by Scotch Education Department.
- A1. Board Schools inspected by Scotch Education Department.
- B. Schools inspected by Home Office.
- C. Higher-class schools charging fees above 9d. per week.
- D. Institutions not under inspection, where children received free education, and, in addition, were fed, or lodged, or clothed.
- E. Schools not inspected, but charging fees similar to inspected Schools.
- F. Schools in an unsatisfactory condition, through defects in accommodation, or in teaching, or both.

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\* Since this paper was read we have to lament the death of Dr. Kennedy.

The results of this double census showed that there were 228 schools in Glasgow of the relative orders named, giving accommodation for 57,290 scholars. When the census referred to was taken there were on the rolls of those 228 schools 52,644 pupils, with an average attendance of 42,655, while at the present time, by the absorption of many of the smaller schools by larger buildings, the number of schools is only 126, yet the accommodation reaches a capacity for 92,181 pupils. When we mention that the roll at the present time over the city is 88,301, representing an average attendance of 76,521, it will be seen that the development, not only in educational machinery, but in living material, is gratifying in the highest degree.

In bearing out this statement, it will not be without interest for us to contrast the relative number of schools under the various heads we have mentioned as to their classification in 1873, before anything practical was done in connection with the carrying out of the Educational Act, and the relative number of schools that stand under the same heads at the present day.

At the beginning of 1873, there were in Glasgow 89 A Schools inspected by Scotch Education Department, while in 1890 there were 24.

A1 Schools, 1873 : Board Schools, none ; in 1890, 66, with 78 separate buildings.

B Schools, 1873 : Schools inspected by Home Office, 9 ; in 1890, 6.

C Schools, 1873 : Higher-class schools charging fees above 9d. per week, 55 ; in 1890, 24.

D Institutions, 1873 : Not inspected, where children received free education, and, in addition, were fed, or lodged, or clothed, 13 ; in 1890, 3.

E Schools, 1873 : Schools not inspected, but charging fees similar to inspected schools, 29 ; in 1890, 2.

F Schools, 1873 : Schools in an unsatisfactory condition through defects in accommodation, or teaching, or both, 33 ; in 1890, 1.

But perhaps the most significant item in all this comparison is the fact that in 1873 there were 33 schools of the F class—that is to say, schools that were unsatisfactory on account of accommodation, or teaching, or both ; and now we are happy to say that there is only one school in this large city occupying that unenviable position.

It will be at once obvious to this meeting that one of the most serious and engrossing difficulties which our first School Board had to face and contend with was that of finding in the various districts adequate temporary accommodation till permanent schools should be erected.

The compulsory clause was now in force, and the School Board were now placed in the anomalous position of being legally, as well as morally, bound to provide education for a large number of children of school age for whom they had no immediate accommodation. The interesting, if somewhat unpleasant, task was, however, bravely faced, and halls, old factories, derelict churches that had long ago finished their theological voyaging, and similar buildings, some of them awfully picturesque in their decay, were eagerly pressed into the muster roll of the educational institutions of the city. These nondescript buildings were leased on short tenure till new schools were erected. They were, of course, in many cases unsavoury in situation and unlovely to look upon, but with the Board it was a matter of "Hobson's choice," and surely if ever a noble end justified unconventional means, it was in these memorable and satisfactory efforts of Glasgow's first Board to find accommodation for the thousands of children with the care of whom they were so suddenly charged.

It can be readily supposed that some of these makeshift places were sadly deficient both in accommodation and comfort, and we to this day carry with us many a mental photograph of these scenes, which were alike picturesque and humorous. We remember visiting one of these temporary "academies," the roof of which was literally, to a most undesirable extent, letting in "celestial light." The day was cold and stormy, and when we entered the little school we actually found the lady teacher pursuing her work sheltered under an umbrella to protect herself from the snow, which was making its way through the roof above where she was standing. Never in all our experience had we seen such a charming paradox—a lady teaching *the elements* and *sheltering herself from the elements* at the same time!

In the course of our official reconnoitring and journeys of discovery we came across similar picturesque-looking "institutions," many of them, of course, being adventure schools of the humblest or most miserable character. One of these was a dame-school, whose comprehensive structure had reached the classic dignity of a "but-and-a-ben." The kitchen served as the teacher's "residence,"

while the room, with an accommodating spirit which was truly commendable, served as the class-room, gymnasium, and playground. The dame who taught the school was a bit of a philosopher, and did not believe in her pupils being idle. She therefore had the wooden bottom of the bed taken out, and to the recess thus cleared she relegated the little ones in rotation when they were not being taught. And thus it was that, while she had a class in hand, the remaining young spirits were playing at "jing-a-ring" in the happy hunting ground of the bed recess.

In another instance I remember coming across, one Monday morning, a number of scholars assembled in what appeared to be an old weaver's shop. The floor was of mud, and the "institution" was but dimly visible through clouds of smoke. On asking for the "master," a small boy, who appeared to be in charge for the moment, came forward, and, in a stage whisper which would have done infinite credit even to J. L. Toole, said, "Please, sir, this is the day we pay our fees, and he's in the shop next door." It would be superfluous to characterise the nature of the "shop next door," and it did not require any very complex reasoning to see that that man was combining porter with penmanship, and geography with "Glenlivet."

I propose to submit my subject to you under four heads:—

1. School planning.
2. The system of lighting.
3. Furniture.
4. Heating and ventilating.

The first school which the first Board decided to erect was in Sister Street, known as Sister Street Public School, designed by Mr. H. H. Maclure, architect, which school, as you are aware, is now demolished to make way for the Bridgeton Cross Extension Railway.

The Board experienced great difficulty with the Education Department before any satisfactory arrangement could be come to regarding the matter under consideration. Specific objections were raised regarding the size of the playgrounds and the shape of the class-rooms. Against the "official" proposals the Board made a pronounced representation, both on the ground of economy and educational efficiency. To submit to the ruling of the Department would largely increase the expense of each school which would thereafter be erected. As the case in point was a

test one, the Board took a firm position, and ultimately the Department conceded the points for which the Board contended, insisting at the same time that the boys and girls should enter the class-rooms by separate stairs, and should not mingle until they were under the eyes of the teachers in their respective class-rooms. The Department also insisted that the girls and boys should have separate playgrounds and lavatories.

Although the Department made a concession with regard to the extent of the playgrounds and width of class-rooms, still the question of separate stairs and passages for boys and girls became sometimes a very complex one in connection with the internal arrangements of the schools. The architects, frequently much perplexed in mind, had to face the difficulty by erecting ingenious but somewhat complicated stairs, so complicated, indeed, that they reminded one of the "mazes" within Hampton Court grounds, and would lead many a stranger to imagine that the Board's new schools were "fearfully and wonderfully made." In one instance (and I have no doubt the same thing frequently occurred) an old lady, by a long process of meandering, had found her way to the top flat of one of these new schools, but there got completely lost, and when found by the janitor, she exclaimed, in undiluted doric, "Hech, sirs, this is a braw schule, but it's unco apt to ravel ye ! I've been wanderin' here for twenty meenits, an' I canna get oot." It may be stated here that the Board have very wisely spread the work of designing their new schools amongst a number of architects, instead of confining themselves to the products of one artistic mind or firm, as is the case in London and other cities and towns. I am sure that this plan of the Board will commend itself to every person in this representative meeting, for, as will be obvious, by widening their field of choice, they not only secured a greater range of artistic genius in their service, but they help to encourage and foster school architecture as a profession over the city.

I would now present for your critical inspection the plans of what I consider a model school, designed by Mr. Robert Bryden, architect. It is not for me to be technically dictatorial to you, many of whom are either constantly engaged in art professionally, or are more or less in touch with it. I simply desire to show on plan a suite of class-rooms so arranged as to be best fitted for the teaching of all the branches of education in a large and well-appointed school. (See Plate II.)

It will be observed that the plans indicate a square building, having a large central hall measuring 45 feet by 25 feet 6 inches, the entrance for the boys being at one end, and that for the girls at the other. The infants' entrance leads into the infant department, which is entirely separated from the divisions assigned to the other departments of the school, and is exclusively set apart for the infants, with whose playground and offices it directly communicates. It cannot but be seen that this is an arrangement which is alike considerate and wise, on account of the tender years of the children to whom it is allotted; and I am sure it will commend itself to you all. The infant department consists of one large room accommodating 157 scholars, and four class-rooms, each accommodating 40 scholars, at 8 square feet per scholar. Two class-rooms can be thrown into one.

The other half of the ground floor consists of four class-rooms for the initiatory department, two accommodating 70 scholars each, and two class-rooms accommodating 60 scholars each, at the space assigned by the Education Department, 10 square feet per scholar.

On the first floor there are four class-rooms, each capable of containing 70 scholars, and other four, each capable of containing 60 scholars, junior and senior. All these rooms are calculated at 10 square feet per scholar.

The rooms in question are 26 feet wide, and this, in my opinion, is the best width for teaching purposes; for when a class-room is, say, 28 or 30 feet in width, the distance from the teacher when he is at the blackboard is so great from the scholars in the back seat of the room that they have much difficulty in hearing him unless he speaks loud. The same difficulty would induce the scholars to speak with an unseemly loudness, a practice which, you will admit, is most objectionable, and not on the lines of refinement or culture.

You will observe that while the class-rooms are four in number on each side of the school, the arrangements are such that, by the opening up of the sliding partitions, they can all be thrown into one large hall. The advantages of this arrangement, as will be at once obvious to you, are great. The plan is serviceable in many ways, even in the routine of school work, such as in giving an object lesson to grouped classes, or singing lessons under the same conditions. It is also most serviceable at public distributions of prizes. These partitions consist of three leaves, one a fixture, the





others sliding and running on a dado about 3 feet high. The sliding doors are 7 feet high, while the remainder of the height is occupied by a dead light 4 feet high, the whole height from floor to ceiling being thus 14 feet.

We shall now go to the second or top floor, and shall carefully consider the various class-rooms as they are specially arranged.

One side of the building contains a large room for elementary drawing, one smaller room for advanced drawing, and the remaining room for drawing and shading from the cast and for other branches of higher art. The roofs of these drawing rooms are constructed on the principles of a factory roof, admitting the light from the north. On the other side of the building the large room in the centre is a lecture room, the one to the right is a laboratory for practical chemistry and physics, to accommodate 24 students, while the one to the left is fitted up for practical cookery. The lecture room can be used for theoretical chemistry or demonstrations in cookery.

All the class-room doors open either way. It is most important that such doors should in all cases open on this plan, thereby giving not only an additional sense, but also the additional fact, of security in the event of any unforeseen emergency arising. In the generally fine order and discipline which are maintained in the Board schools, such a thing as a panic could never occur in the ordinary course of school routine, but there are eventualities which might arise in the most finely ordered of our schools, such as the alarm of fire, and in the event of such arising, if the doors did not open either way, it can readily be imagined that the results might be most disastrous.

Glass demonstration boards are placed on the walls of each room. The positions of these boards in the various rooms should be judiciously selected, care being taken that they be not placed in the centre, as by such an unfortunate arrangement the scholars sitting on the left side of the room would be prevented from seeing the demonstration, from the fact that the teacher would at the time be standing between them and what was under consideration on the board.

These glass boards are a very marked improvement on the wooden ones, as the figures or demonstrations can readily be seen by the scholars at any angle. The best size of a board is 6 feet by 3 feet. The glass used is  $\frac{1}{4}$ -inch thick, finely ground on the

face, and painted on the back with three or four coats of black paint.

The stairs are at each end of the building, and are about 5 feet wide, the risers of which are never more than 6 inches higher.

On the first and second floors there is a passage round the walls about 4 feet wide. Each passage is supported on steel girders projecting from the class-rooms through the internal walls, and the passages are filled in with concrete and finished with granolithic paving. The whole of the galleries, stairs, and central hall are abundantly lighted from the roof by a large cupola. The walls of the central hall, stairs, and corridors are lined with enamelled tiles of different colours.

It may be stated here that the provision of wash-hand basins in the girls' section of the schools is a matter which has received the special attention of the Board during these latter years; and it is now specially necessary that an ample supply of these wash-hand basins be kept on each floor for the use of the girls, for the Education Department insist that the specimens of sewed work presented to H.M. Inspector should in no case be either washed or ironed. It will be obvious from this rule that it is most essential that the hands of the girls be thoroughly clean before they begin their industrial work. It has been a matter of extreme difficulty to make these basins at once artistic, economical, and serviceable. From the nature of my daily duties in connection with the fittings of every one of the new schools which the Board have erected during these eighteen years, it has naturally fallen to me to study, among many other things, the question of lavatories under the three aspects named.

Were it not that the matter has special reference to the subject under consideration to-night, it would have ill become me to have mentioned a special form of basin which, with the assistance of the head-master of Abbotsford School, I have designed. But I am confident, on the other hand, that it could, with justice, be set down as false modesty if I withheld what I may be entitled to say on the subject. In the frank spirit, then, of interchange of ideas which we can all claim on any point in invention or improvement, I shall submit the matter to your critical consideration. The trough is extremely simple in its construction. It consists of one continuous basin, containing 2 inches of water, with a receiver to carry off all scum and refuse water when in use by the children. The supply is admitted by a perforated copper tube

laid inside the trough at the back, with apertures directed towards the front. The pressure of water coming out of this tube produces a wave which strikes against the front, rises, and passes across to the back, carrying away the refuse water, and thereby preventing all risk of infection. There is little or no plumber work in connection with the trough, consequently the upkeep is reduced to a minimum.

The gas arrangements for the adequate distribution of light in the various class-rooms have been vastly improved of late years. Instead of one corona of 24 lights placed in the centre of the room, I would recommend three smaller lamps of four jets in each, placed as I have shown on the plan before you. This new arrangement with 12 jets will brilliantly light a room containing 70 scholars at 10 square feet per scholar. Gas pipes, in my opinion, should not be concealed behind the plastered walls nor under the floor, but should be placed on the outside of the walls and ceilings, so that any escape can easily be detected and rectified. A stop-cock should be placed in each class-room, under the control of the teacher, who could turn the gas off or on as he or she may desire. I am well aware that architects, from æsthetic or artistic reasons, think that this display of gas pipes on the walls, instead of having them carefully concealed behind the plaster, is an unpardonable revolt against the laws of high art; but, in defence of my preference, I would plead that the easy access to the pipes when a leakage occurs justifies me in recommending this method. It is no uncommon occurrence for a teacher, in driving a nail in the wall on which to hang a map or picture, to drive it through the gas pipe, thus causing an escape which cannot be repaired without stripping the wall-plaster, and thereby causing not only unnecessary expense, but also great inconvenience, mingled, it may be, with mutterings that are neither parliamentary nor polite. I may mention that all the gas pipes used in the Board schools are made of iron.

It is natural that at this stage I should say a word concerning the kind of lamps that are preferable for use. I submit for your inspection the "Stott-Thorpe" lamp, which is the best I have ever tried. This light is arranged under a white enamelled cone without any aperture in the top. The products of combustion do not enter the cone, but are carried outside by the natural action of the air, which is drawn up the centre of the cone between the burners, and, after feeding the flames on the upper side, passes outwards.

The light increases in brilliancy after burning for a short time, as both air and gas become heated before combustion takes place. I may state here that I tried these lamps in one of our evening schools last winter with the most satisfactory results, so satisfactory, indeed, that the Board have since had them fitted up in two of their schools.

It now falls to us to consider the question of school furniture. Till within the past few years the style of desks used in our schools varied from 6 to 9 feet in length, without backs. They were placed on raised platforms, having behind each row a passage about 13 inches wide to allow the teacher to pass in rear of the scholars. You will see at once, that if backs were attached to the seats, it would be impossible for the scholars to leave the desk without climbing over the back rail. You are all aware how detrimental it must be to the health of children to sit all day without a support to the back. This matter had to be considered, and I am glad to say it has been remedied by the adoption of the improved dual desk. The old dual desk has many defects, such as the want of slate slits and book shelves, and can only be used on the floor level, or on platforms the rises of which have to be all of the same height. All these defects have been remedied in the sample I submit for your inspection. The improvements in this desk were suggested by the head-master of Washington Street School, and successfully carried out by the Bennet Furnishing Company, of Glasgow and London. The head-master of Napierhall Street School, writing to me regarding this desk, says that it is, without doubt, "the desk of the future."

The subject of warming and ventilating is perhaps the most difficult among all the questions which arise in connection with school architecture. The building requires, not warmth alone, nor ventilation alone, but the two in combination, each efficient, thorough, and ample. The system hitherto adopted by the School Board is the introduction of mild hot-water pipes placed round the walls. These pipes heat the particles of air with which they are in contact, and thus transmit warmth, but, as you know, this result is not enough. The vitiated air must be carried away, and a supply of fresh air introduced to take its place.

In some cases the method hitherto adopted for the introduction of fresh air has been the Tobin system—that is to say, by openings made through the outer walls, and carried into the class-rooms in a wooden box or iron tube about 5 feet or so above the floor level.

In other cases the windows are drawn down from the top. This latter method is not satisfactory, as the fresh air descends directly on the heads of the children. In the former case the method is more satisfactory, but depends very much for its effect on the direction and strength of the wind.

On a dull, sluggish day, when there is little or no wind, it is impossible to introduce as much fresh air through the tubes as will drive the vitiated air through the apertures in the ceiling. On the other hand, when the wind is high, draughts are created which in many cases cause the teacher to close the ventilators altogether. In one instance I was sent for to one of our schools to examine a class-room which was said to be defective in ventilation. All the rooms in that school were fitted up on the Tobin principle, and in this particular room, three tubes were placed for a supply of fresh air. On making an examination of the inlets, I found that the teacher had stuffed them up with newspapers, on the plea that the draught might give her a cold.

The most satisfactory method of introducing fresh air into a class-room by natural means is to fix a glass screen about 20 inches deep at an angle of, say,  $60^{\circ}$  on the inside of the window, so that by lifting the lower sash by means of cords and pulleys about 5 inches, a supply of air is carried into the class-room above the children's heads, and this has the effect of driving the vitiated air out through the openings in the ceiling or the inner wall. The extraction of foul air is very much assisted by placing an extraction ventilator connected with each flue on the roof of the building.

The supply of fresh air depends very much on the attention paid by the teacher to the opening of the windows, but we all know that this is very often neglected, with the very worst results.

I would now submit to you a plan prepared by Messrs. James Cormack & Sons, heating and ventilating engineers. This plan shows a method of heating and ventilating by mechanical means. I may state here that the heating and ventilation of Annfield and Queen Mary Street Public Schools, now in course of erection, were intrusted by the Board to Mr. William Key, of Glasgow, who so successfully planned and carried out the heating and ventilation of the Victoria Infirmary, and several schools in Aberdeen and elsewhere.

The inlet for fresh air is intended to do duty for the open windows which formerly admitted the fresh air, and the motive power to induce a current of air is the "Blackman" fan, 5 feet in diameter, standing at the entrance to the main duct, which runs from end to end of the building. The fan is propelled by a four-horse power "Stockport" or Crossley's "Otto" gas engine standing in the engine room near the duct. At all times the incoming air undergoes the process of cleansing and warming, the second operation being necessary only in winter. The cleansing is effected by means of a screen of fibrous material, which is kept moist by an occasional flush of water from a trough placed above the frame. All the particles of soot and dust are by means of this screen arrested on their way into the building and washed off. A coil of hot-water piping stands outside the washing screen to protect it from frost, but the real warming of the air occurs when the screen is passed, and the entering current comes in contact with the larger coil of high-pressure hot-water pipes occupying the chamber in front of the fan. In ordinary winter weather pure air at a temperature of  $70^{\circ}$  is propelled by this means into the main duct, from whence it finds its way up to the class-rooms at a temperature of  $5^{\circ}$  lower. In very frosty weather the heating of a second coil of pipes gives the necessary additional warmth.

By this method all the class-rooms, staircases, and lobbies receive a continuous current of pure air sufficient to renew the atmosphere in every class-room from four to eight times per hour. Having discharged its function, the air is expelled through outlet flues, which may be placed either at the floor level or ceiling, entering a chamber in the roof, and passing out to the open air. Draughts or currents of air are not felt in the class-rooms, notwithstanding the continuous change of air occurring within them. The first cost of heating and ventilating a school by mechanical means is about £300 more than by the ordinary natural system.

I may also state that the Board recently fitted up a workshop in the City School for manual instruction. This workshop accommodates 38 boys, who are taught, under a specially qualified teacher, to plane, dovetail, mitre, half-check, and to do other forms of joiner work, for which the Education Department give a grant of 7s. per scholar.

The girls in the fifth and sixth standards are taught washing and laundry work in Petershill School, and seven tubs, with hot

and cold water appliances, are fitted up in the basement of the school for that purpose. The girls are taught in sections of 14 at a time, two girls washing at each tub. After having been washed and dried, the clothes are then taken to the laundry room, where the starching and ironing processes are carried on. The Education Department also award a grant of 2s. per scholar for this work.

VIII.—*The Rural Economy of Scotland in the time of Burns.*

(Illustrated by Lantern Views specially prepared from Contemporary Prints.) By JAMES COLVILLE, M.A., D.Sc.

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[A Communication from the Philological Section read before the Society, 16th March, 1892.]

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THE career of Burns—1759-96—is almost co-extensive with the latter half of the eighteenth century, a period in our history of momentous importance. It significantly opens with the abolition of the heritable jurisdiction of the barons in 1748, and closes with the quiet disappearance of the last relic of feudal serfdom in 1799, when the colliers and salters were relieved of the sole remaining link in the chain that had for centuries bound them to the soil. This period witnessed the rise of all our modern industries, and the complete transformation of the only hitherto existing one—agriculture. It witnessed also both an enormous expansion of the population—twice has it doubled itself since the youth of Burns—as well as a surprising redistribution of it. At the end of the century 55 per cent. of the population were living in hamlets and homesteads of under 300 inhabitants. Further, it was the period which, in spite of the stern repression of the Dundas rule, evolved such questions as the rise of dissent, road reform, poor laws, burgh reform, elementary education, all which have so profoundly affected our own well-being. But, above all, it gave us the greatest and most typical of modern Scotchmen—Burns, Scott, Carlyle. Yet our historians, great and small, have nothing special to say of it. Burton and Chambers both stop at 1748. It may safely be said that from the large stock of contemporary material tabulated at the end of this paper, no general conclusions have, as far as I know, been yet presented to the public. In the literary aspect of the subject, apart from its historical interest, Scott and Carlyle are largely their own interpreters, but the lights and shadows of Burns' life and work cannot be properly understood and sympathised with unless some such study be made of this contemporary material.

It is possible to form a very complete idea of the general appearance of the country during this period. Down almost to the close of the century, except in a few sheltered river valleys, a Scottish landscape presented few pleasing features. All the travellers from the more favoured South bear out Dr. Johnson's famous observation on the general treelessness, without his rather heavy fun, and almost every page of the "Statistical Account" supplies corroborative evidence. Even Burns, who cannot be accused of lack of patriotism, finds a similar state of matters, and this even where it was least to be expected, as is shown by his lines on Bruar Water. Pennant found some hedges and traces of plantation around Edinburgh. The city itself must have had clumps of trees, for Cockburn deploras the vandalism that was cutting them down in his day to make way for the New Town. Pennant saw, in going to Perth by Kinross, few trees, except about Blair and Perth itself. Further north, over the Grampians, all the way to Inverness, matters were still worse. Moray and Aberdeen were little better; but the Mearns and the Carse of Gowrie, on the east side, and the lower reaches of the Clyde above Dumbarton, afforded charming prospects of wood, water, and rich corn fields. Topham saw many a wide view without the appearance of vegetation higher above its surface than a blade of grass. There was but one orchard in Edinburgh, and hardly another in the country. Good apples were not to be seen, and turnips formed the only dessert. Lettice says nothing could exceed the dreariness of the Upper Ward of Lanark. Heron thinks Nithsdale would be beautiful with clumps and belts of wood. It is not quite bare, but there are few trees. Drumlanrig Castle has an air of decay and desolation, thanks to the sordid avarice of the then Marquis of Queensberry, so vigorously denounced by Burns. The banks of the Stinchar, Heron saw unadorned by trees or underwood; Magnus Muir remained wild, unenclosed, and untilled, probably as at the time when Sharp was murdered. Both districts are now richly clothed in foliage.

In this matter of forestry a great change was in progress during the last quarter of the century. Then were created such famous scenes of sylvan loveliness as the Kelvingrove and Aberdour woods of the olden time, Cambusmore, Duplin, Drummond, and Glamis Castles, and the like. Many noted forest patriarchs are recorded in the "Statistical Account." Some of them had been for centuries landmarks, like the oak of Balderran, which still stands by the

roadside near Killearn ; the Capon Tree at Jedburgh, associated with Burns, or the Fortingal yew, reputed to be the oldest vegetable in Europe. But, upon the whole, Johnson was not far wrong when he said there were few trees in Scotland older than himself. The beech, indeed, was not known at all before the 18th century, and with its introduction the squirrel appeared from England. The larch was imported fifty years later. The first walled park was constructed in six weeks at Tynningham, in East Lothian, in 1681, by the Earl of Lauderdale, to please the Duke of York.

Here and there the natural or self-sown woods survived in deep dens and sheltered nooks, and on many an upland glade, for the country had always been sparsely peopled. The Reformation was effected in a country of only half-a-million, all told. Oak would root itself firmly in the valleys, ash and willow on the sides of every brook, alder in swamps and spouty land ; while the birk would hang its fair tresses, and the rowan its roseate clusters, on the front of every scaur. In some cases these natural woods out-lived feudal times. The Kirk of Forest extended for ten miles to the east of Ayr, but this, says Fullerton (writing in 1793), and every forest, has long gone, except Dalrymple Woods, on the Doon. Fifty years ago, he adds, there was hardly any timber in the country except natural oak and birch on the river banks, with clumps of ash and plane round some farm-houses. These natural woods Burns dearly loved, and a great part they play in the scenery of his poetry.

The general features of the landscape are abiding. The rivers then ran their fitful race in their present channels ; the hills outlined themselves, as now, against the glowing west. But the former flowed on between more open banks, and sheep have changed the dark heathy tints of the latter to a pleasant green. The draining of vast swamps, the profusion of hedge-rows in many districts, the coverts that have sprung up in this age of sport, the policies surrounding the mansions that have grown with the nation's wealth—these have all effected a marvellous change. Last century illustrations all support the testimony of contemporary observers. There we have the ever-flowing streams and the eternal hills, but the whole aspect seems strange to modern landscape. The historic sites, shown in all their nakedness by Grose and others, can be approached by the modern photographer only with difficulty.

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The reason for this general absence of trees in Scotland is to be found neither in climate nor in the direct action of man, but in the ancient system of husbandry. In the absence of enclosures ; the entire stock of each crofter township roamed everywhere as soon as the crop was off the ground. There being as yet no turnips nor sown grass, but only a little coarse hay from the bog-lands, every green thing would be eaten up that was within reach. There would be plenty of self-sown trees, but few would ever have a chance of surviving. Darwin closely observed a measured patch of common in Kent, exposed to such conditions as generally prevailed in the ante-enclosing days, and though he counted hundreds of seedling trees, not one grew above an inch or two before being cropped off. In such circumstances, alder in the marshy places, and birches on the river scaurs, would alone have a chance of surviving. The two homeliest of trees were the alder and the elder, and both play a great part in folk-lore. In the shades of the former lurked the goblins and brownies, while the latter was used to enclose the kail-yards, as the cattle refused to touch it, and there Burns places it in his Address to the Deil :—

“ When twilight did my Grannie summon,  
To say her prayers, douce, honest woman !  
Aft yont the dyke she's heard you bummin,  
Wi' eerie drone ;  
Or, rustlin', thro' the boortrees (elder) comin,  
Wi' heavy groan.”

The universal absence of enclosures has left its mark on the Scottish law of trespass, so favourable to the trespasser. Under ancient conditions there could be no such thing as trespass without clear proof of damage done. In many districts the country remained, to the close of the century, quite open. In Strathallan, during the last decade, so great changes had been effected by enclosing that it was no longer thought bad neighbourhood to drive off cattle trespassing upon winter crops. When enclosing was introduced into Galloway it was very unpopular. Men went about in women's clothes levelling the dry-stone dykes. Elsewhere these were blamed for making people take round-about roads, and as ruining the time-honoured industry of the herd, who played an important part in the economy of the township. Great numbers were boys from the Highlands, who thus earned a welcome pittance, and picked up English enough to better their condition. In the Lothians they formed themselves into parish

guilds, and with their horns and bravery used to meet regularly to kindle the Beltane and hold the Lammas festival. For the latter these built pillars of divots or turfs, leaving in the centre a place for a pole, which bore a blanket, granted by some well-disposed housewife. Rival parties tried to demolish each other's towers, and vigorous bickers ensued, a practice still followed by boys, though the custom survives only in a debased form. The work of the herd began with the sowing of the bear, and lasted till the crops were housed. There are few more picturesque figures in literature, down from mediæval times, than the blue-bonneted herd laddie. His badge was the crook with the stock-and-horn. The latter Burns struck on his seal over the motto, "Better a wee bush than nae beild," and carefully explained its construction in a letter to George Thomson, for the benefit of the artist, David Allan, who was, however, the proud possessor of one already. The tip of a cow's horn was to be cut off, and in the aperture the shank bone of a sheep inserted, and in that again an oat-straw. The necessary stops or vent-holes were to be added.

To save the growing crops and spare the herd, the cattle were confined during the mid-day hours and over night in a fold built of turf.

"The shepherd steeks his fauldin slap,  
And owre the moorland whistles shrill."

In the west such a fold is still called a *fank* (Ger., *fangen*, to seize), and in the north-eastern counties the *pumfle*, a corruption of pinfold. The rustic mind was struck with its likeness to the high pew at the stair-head in the old-fashioned church loft, a favourite resort of the boys, even in living memory, as a safe place for marbles and other sports. It was a Buchan minister who, on his rounds, thus accosted a boy that he suspected of neglecting ordinances—"Laddie, fat wy de'ee nae gang t' i' kirk?" "Sae I dee," replied the boy, "but ee ken a' sit ee i' pumfle," where, of course, he could be out of sight.

The land in these times was generally held by kindly tenants or rentallers—feudal retainers, in fact—who built their houses and yards close together in townships round the kirk or castle. The tenure was leasehold, with easy rents, paid in kind. There was a homely tone of neighbourliness between the tenants and the laird. The Earl of Moray, present at a *kirn* or harvest-home, saw a tenant dancing merrily at seventy. "John," he said, "you are too rich and wanton; I must raise my land rent." "My

lord," replied John, "it's not the land that has made me rich, but God's providence and the change of wives." Sometimes, however, there intervened between the crofters and the laird the bonnet-lairds, or lesser feuars (tacksman in the north)—that is to say, tenants who had power to sublet, and these were often oppressive and unpopular. The land was generally let in plow-gates of fifty acres each, held by four tenants in common, employing four horses. About half would be arable or *infield*, laid out in *run-rig*, that is to say, long serpentine ridges, very narrow and high in the centre, and always more or less wet at the sides, where there was a rude surface drainage. Between these were strips in natural grass, called *banks* in some places, *fauchs* or fallows in others, and here the gudewife or young callant or auld carle was wont to bait the cow, secured by the head stall or *branks*, the herd all the while busy knitting stockings or spinning with the distaff or whorl-spindle, which, by the way, Sir Arthur Mitchell found in use only thirty years ago. Beyond the infield was the *outfield*, or portion under natural grass, and here was the *pumple*. This portion, manured by being enclosed, was said to be *tothed*, that is to say, tethered, and when broken up in the following season was kept in oats or bear till exhausted. It was then overrun with weeds until the grass recovered. Much time was taken up in cutting the rich crop of thistles to supper the work-horses that could not be turned out to graze. Outside all was the common, so poor as to be fit only for pasturing a few sorry sheep, or growing *hainings*—that is to say, broom, heath, whin, &c., to secure a bite in winter. Here, too, were cut the turfs, or *feal divots*, for roofing and for the walls of huts, or mixing with manure to form a compost or *fulzie*. Such land was greatly impoverished by these periodical parings. Over the greater part of even the Lowlands run-rig prevailed till near the end of the century. These were the days of Small Allotments, and, where the system prevailed, progress was slow in the extreme. The worst cases were in such places as Inveresk, Kilmaurs, Johnstone, &c. The Glencairn family made the experiment in Kilmaurs of fostering village industries by giving crofts to the weavers. Here, as in the neighbourhood of small burghs, these allotments were greatly neglected by the tradespeople, who held them on easy terms, and made little either of trading or farming.

In a society of few wants, and these supplied by home industry, money was scarce, so that rents were paid in kind. This took

the form of labour on the laird's farm or demesne (the *Mains*), teind corn, and *kain* fowls, the *cens* of the Ancient Regime in France. The Earl of Aberdeen had a granary at Tarland that held 600 bolls yearly. In the dearth of 1782 the people of Tarbat, in Easter Ross, stopped a ship laden with teind corn for Greenock. Feudal services survived in many places to the end of the century. They were known as *arage*, or so many days' ploughing; *carage*—that is to say, casting and leading a *leet* or stack of peats or carrying coals; *bonnage*, harvesting hay and corn; and *thirlage*, or multure.

“Our laird gets in his racket rents,  
His coals, his kain, and a' his stents” (dues).

Burns' “*Twa Dogs*.”

Thirlage was a bitter grievance. At Rutherglen, by 1793, the burgh lands were thirled  $\frac{1}{10}$ th, with bauk-meal to the miller and to his knave or man. Kilwinning was thirled to the Abbey and Lord Eglinton; Paisley to the Abbey,  $\frac{1}{20}$ th, besides knaveship. In Nithsdale, multure was held to apply to wheat ( $\frac{1}{17}$ th), though the laird had no mill to grind it. It had been an ancient obligation to take all the corn to the baronial or abbey mill, hence the farm was said to be *thirled* or astricted to this mill, and had to pay a multure or portion of the meal to the miller, sometimes as high as  $\frac{1}{12}$ th. Horse and seed corn were excepted. The portion of corn taken to the mill each time was called a melder. Tam o' Shanter's wife, Kate, complained

“That ilka melder wi' the miller  
Thou sat as lang as thou had siller.”

In consequence, no doubt, of these exactions, the quern or primitive hand-mill was in constant use.

“The cronach stills the dowie heart,  
The jorram stills the bairnie,  
The music for a hungry wame  
Is grindin o' the quernie.”—Robert Jamieson.

In the north querns are still in use, and a livelihood is earned by making and selling them. They cost from 3s. 6d. to 5s. each.

The ground had been cropped from time immemorial in a rotation of oats, pease, and bear or *bigg*, a kind of coarse four-rowed barley. This was kept up till the land gave only two seeds in return, four or five returns being a good crop. White oats came to supersede the old grey variety; while wheat was raised only in the Lothians and carse lands even near the close of the century.

Little progress could be made anywhere until alternating husbandry was rendered possible by the introduction of rye-grass and clover, turnips and potatoes, and these were the agents in transforming the face of the country and the entire rural economy. From this followed, as a matter of course, planting of trees for shelter, enclosing, draining, liming, stall-feeding, and the consequent increase of manure; grazing in parks instead of herding, in which the cattle were tormented by the dogs and half starved; the rise of large farms in the hands of capitalists, accompanied by the decay of the crofter and the depletion of hamlets to fill the towns and increase vagrancy, pauperism, and crime. These changes were initiated and sent well under weigh during the short life of Burns. His father's lease of seven acres of Doonholm, in 1757, was typical of the expiring effort of the old husbandry; his own retirement from Ellisland to the Wee Vennel in Dumfries, 1791, was the tacit recognition of the new order of things. The change began at the close of the Seven Years' War in 1763, but culminated in the high prices that prevailed during the long wars with France.

Swift calls the man who makes two blades of grass grow where one grew before a public benefactor. What is to be said of the men that gave to modern farming sown grasses, turnips, and potatoes? The sowing of grasses and clover spread very slowly. The people looked upon such improvements as a freak, like hunting and horse racing, all very well for the wealthy lairds who could afford to lose on expensive experiments. The attitude of the peasants in this connection is shown by the public opinion of Methven, that it was a shame to see beasts' meat growing where men's should grow.

Turnips formed as great a boon for winter feeding as rye-grass and clover for summer. Lord Townshend introduced them into English husbandry in 1730. Their introduction into Scotland was not a little romantic. James Dawson, a farmer near Roxburgh, went to Leicester, and hired himself to Bakewell, the famous sheep-breeder, as a ploughman. He left in six months, against the wish of Bakewell, going north, however, with a scheme for drill husbandry in his head. In the following year he had 70 acres of turnips sown. This was about the year 1760. The turnip had been known before this, and sown in gardens, like cabbage, but broadcast. The minister of Kinellar, in Aberdeenshire, unwilling to weed a bed of turnips growing in this fashion

in his garden, and thinking it would not succeed, tore up the greater part with the hoe. The crop turned out better than had ever been seen before, and in a few years hoeing in drills became general. Curiously enough, hand-thinning in the fields by crawling on all fours is still general over south-western Scotland. Turnip growing was, however, long in becoming general. Reports in the last decade of the century say :—Galston, few turnips yet raised ; Nithsdale, no turnips ; Whittinghame, only twenty years since turnips were generally known in East Lothian ; Kemback, Fife, no turnips or sown grass a dozen years ago, fields exhausted by cropping ; Killearn, turnips not tried in the open field ; Stevenston, turnips not yet tried ; Cluny, Aberdeen, turnips sometimes in drills, but broadcast preferred, as giving a larger crop. Of course, under such circumstances, butcher meat was not in condition till August, and for winter supplies a *mart* had to be killed at Martinmas (hence the name), and kept in pickle. Even in the capital it was little used. Sir David Kinloch, in 1732, sold from his Lothian farm ten wedders fattened on his first rye-grass, and the buyer, an Edinburgh butcher, stipulated that they should be lifted at three separate times to prevent a glut of mutton in the market.

There wanted only another green crop to do for the peasant what the turnip was doing for his stock, and carry the comforts of the summer through the winter. This was the potato, which made even slower progress than the turnip. The way was said to have been barred by the Presbyterian prejudice that it was never mentioned in the Bible. In the Lothians it came in about 1740, the year of dearth, from Ireland, but was confined to gardens till about 1754, when it was planted in fields about Aberlady. By the close of the century it was a general article of diet. Ramsay says that Geo. Henderson went, about 1750, for a bag of potatoes to Kilsyth, where the Irish method of field culture had lately been tried, and introduced the potato into Menteith, where a few had been known, but only in kail-yards. The old folks, however, did not take kindly to the new food. Old George Bachop, one of the Ochertyre tenants, told by his wife that she had potatoes for supper, said, "Tatties, tatties! I never supped on them a' my days, and winna the nicht. Gie them to the herd, and get me sowens." It is significant that Burns, who sings the praises of kail, and porridge, and haggis, has nothing to say of the potato.

The ploughing of the small open fields long advanced but little beyond primitive methods. In the north small horses or *garrons* were used, but in the south and in the north-eastern counties oxen were used. They survived longest in Aberdeenshire, being still so employed even yet in Deeside. At Alford, in 1795, every farmer was ambitious of having as many pairs of oxen in the plough as he could. Oxen are to be found at work near the end of the century about Dundee, St. Andrews, Dumbarton. In the Lothians, towards the middle of the century, it was customary to send the work-oxen, after the bear seed was in, to the Braes of Leny to recruit, at two merks a head, and twopence to the herd, and there they remained till the crop was in. Lord Kames, a noted improver, was a great advocate for the use of oxen in labour, but they disappeared with the spread of turnpike roads and the much longer journeys that then became common.

The old Scotch plough was a clumsy survival from Roman times. It was not unusual to see it drawn by four or five pairs of oxen. Long after the middle of the century the plough *graiith* was made on the farm—the long winter nights being spent in preparing it, for no plough was brought out till Candlemas, and then to the accompaniment of rude rites handed down from heathen times. The timber forming the body of the plough was brought by the Highlanders to Doune Market, along with the black cattle, at Martinmas, and sold for 1s. and 1s. 6d. a-piece. It was a Berwickshire man, James Small, who, from a few models which he found, improved (about 1766) on a plough introduced by an itinerant English maker, Lammas, nearly 60 years before. His work soon becoming famous, he established a thriving village industry at Edrom. The draught he made so light that two horses only were required. In a few years the driver or gadsman was also dispensed with. His business had been to clear the coulter with a stout stick or *pettle*, which he occasionally flung at the leaders.

“ I wud be laith to rin and chase thee  
Wi' murderin' pettle.”—Burns' “ *To a Mouse.*”

The driver also encouraged the team by whistling, regarded as a great rustic accomplishment, hence the Buchan proverb for much ado about nothing—“ Muckle fusslin and little red land.” In the uplands a third hand was employed down to the close of the century. He held the reins of the team on a short stick, and walked backwards leading them. The defence of anything so

awkward was that, the ground being full of foot-fast stones, they could be better seen in this way and avoided, so as to save the plough.

This picturesque mode of ploughing was practised by Burns, as shown in "The Inventory," a poem which throws much light on the economy of a lowland farm—

" Imprimis this, for carriage cattle,  
I have four brutes o' gallant mettle,  
As ever drew afore a pettle ;  
My han' afore's [near leader] a guid auld has-been,  
An' wight an' wilfu' a' his days been ;  
My han' ahin's [near wheeler] a weel gaun fillie  
That aft has brought me hame frae Killie ;  
My fur-ahin's [off-wheeler] a wordy beast  
As e'er in tug or tow was traced ;  
The fourth's a Hieland Donald hastie."

The "han'-ahin" is the subject of the "Farmer's Address to his auld mare Maggie"—

" Thou was a noble fittie-lan' [foot on land],  
As e'er in tug or tow was drawn."

"The Inventory" goes on to say—

" Wheel carriages I hae but few,  
Three carts, an' twa are feckly new ;  
Ae auld wheelbarrow, mair for token,  
Ae leg, an' baith the trams, are broken ;  
I made a poker o' the spin'le,  
An' my auld mither brunt the trin'le [wheel].  
For men, I've three mischievous boys,  
Run deils for rantin an' for noise ;  
A gaudsman ane, a thrasher t'other,  
Wee Davock hands the nowt [cattle] in fother."

We need not wonder at Burns' statement in the first line. Col. Fullarton, reporting on Ayrshire in 1793, says that forty years ago there was hardly a practicable road, and no carts—produce and manure being carried on sledges, dragged on runners, or placed on tumbler wheels of wood, and turning with the axle. Loads of 5 cwt. were thus drawn, and this was characteristic of the country generally. Roads were little better than bridle-paths, and for longish distances panniers or *currochs* were laid across the pony's back, to which the load was secured, as in Iceland at the present day. At Currie, in West Lothian, hay was taken to Edinburgh in this way in loads of ten stones, exactly as,

in Sir David Lindsay's time, he says, coal was conveyed from Tranent. The body of Burns' father was carried eight miles for burial at Alloway Kirk by a pair of horses yoked tandem-wise, the coffin being slung between on bearers. The usual work of the farm was done with sleds or sledges, still common in the Highlands. They are home made, of the native birch or hazel, without a single nail, and admirably suited for moving hay, corn, or peats, over a rough moor or hill-side, where wheels would be useless. They were also placed on wheels, unshod, made of three pieces, and, as the wood wore unequally, these soon got out of shape, hence they were called tumbler-wheels, or, in Buchan, tumlin-trees. Burns' Jenny Geddes had a stomach, like Willie Stalker's mare, that would have digested tumbler-wheels.

The description of Glaud's onstead or farm-steading in the "Gentle Shepherd" is that of a common type, to be found anywhere in Scotland during last century—

"A snug thaik hoose, before the door a green,  
Hens on the midden, ducks in dubs are seen ;  
On this side stands a barn, on that a byre,  
A peat stack joins and forms a rural square ;  
The hoose is Glaud's, there you may see him lean,  
An' to his divot seat invite his frien'."

In most cases the crofter was, like William Burness, his own mason, and built his "auld clay biggin" himself, with the help of his neighbours. At Errol, in Gowrie, 1792, houses were of clay, there being no stones, and every man built for himself. At Canonbie, 1769, the owner prepares the materials—clay mixed with straw,—summons his neighbours for a day's darg (work), who come with victuals at their own cost, and, setting cheerfully to work, complete the house before nightfall. At Dornock, Annan, in 1792, all the houses in the village, save the manse and two others, were of mud and thatch. In Perth, long the second city in the kingdom, Heron found the houses in 1792 still partly or wholly of wood. At one time there was but little masonry, no skill in quarrying and hewing, and no medium between huts of turf and loose stones, and the splendid castles still so interesting architecturally. At Girvan the houses which Heron saw were huts more miserable even than those of Ballantrae, and so low as to seem rather to be caves dug in the earth than houses built upon it. The minister of Tongland, in Kirkcudbrightshire, draws a gloomy picture of rural economy in his parish—houses of stone or turf, no mortar,

crevices stopped with moss or straw, a window at each side opened for light as the wind blew, and at other times stuffed with straw or fern. The houses of Aberdeenshire farmers were commonly of sod, and consisted of a fire-house, where the family and servants sat and ate, and a pantry, with sometimes an intermediate space for beds and chests. This was a ha'-house. The cottage of a labourer was on an inferior scale. A crazy woman, listening to a preacher in Portsoy on the text, "In my father's house are many mansions," astonished everybody by exclaiming, "My certé, your feether's hoose, auld Baukie's! I kent him weel—a butt and a ben, and that but ill redd up." A minister, rebuking a labouring man for sleeping in church, was told—"It's because I canna sleep at hame for the rattons and the sklaters."

The ordinary cottage had two apartments, a butt end or kitchen, and a ben end or *spence*. The passage inside the door connecting them was the *trance*. The kitchen was the farmer's ha', where, as at Ellisland, master and servants took meals together, and where the "big ha' Bible" was produced for family worship. The floor was the uneven earthen *solum*, and the roof showed its open joists, the bauks or kebars, where hung the winter store of kitchen—that is to say, braxy mutton, with strings of onions.

"He ended, and the kebars shook  
Aboon the chorus roar,  
While frichted rattons backward leuk,  
And seek the benmost bore."—"Jolly Beggars."

Here, too, roosted among the peat smoke, that followed its own course from the great open hearth, the reek hens, that paid the tacksman's kain rent. They entered by a hole in the thatch over the doorway. In the gable, and near the floor, was the dog-hole, by which the collie got out and in at will. A wooden bar-lock secured the door, and when a neighbour called he "tirlid lichtly at the pin." The furniture was on a scanty scale. On either side the fireplace was a small box or *bole*, the one the saut-bucket, and the other for odds and ends. Near by stood the *lit-pot*, filled with dye-stuff, and at one time to be found in every house. The large oaken settle was the guidman's seat, and in the corner behind him stood the chicken-*cavie* or hen-coop. On the wall hung the *haik*, an open rack for homely delft-ware, green-horn spoons, and a variety of vessels—cogs, bickers, quaichs, lugget caups, cooties, luggies, laggens,—and beneath it the deas or dais, a closed cupboard. A

box-bed filled up other parts of the wall. The spence was the state-room, where slept the master and his wife, but almost as modestly furnished.

We have pictures, both pen and pencil, of the cottage interiors of the time. Here is Symon's in the "Gentle Shepherd":—

" A clear peat-ingle  
Glances amidst the floor ;  
The green-horn spoons, beech luggies mingle  
On skelfs foregainst the door."

Mossgiel was for the time quite a superior farm-house, having been built as a retreat for Burns' friend, Gavin Hamilton, the Mauchline writer. The farm was of 118 acres, and the rent £90. The buildings stood high, and formed a square, with the manure heap in the centre. The roof was not thatched, and in the garret, reached by a *trap* or ladder from the trance, slept in the same bed the poet and his man, John Blane. The timbers were coom-ceiled—that is to say, went down open to the crap-wa' or angle at the eaves. On the floor, opposite the small bole or window, stood that unique deal table, whose drawer held those immortal poetic treasures which the poet's sister used to steal up to read. The spence or parlour is equally classic ground, for it was the scene of "The Vision." Wearied with the day's threshing, the poet says:—

" Ben i' the spence, richt pensively I gaed to rest :  
There, lanely by the ingle cheek,  
I sat and eyed the spewing reek,  
That filled, wi' hoast-provoking smeek,  
The auld clay biggin,  
And heard the restless rattons squeak  
About the riggin."

After the "Forty-five," it is said dress became less picturesque. The repressive legislation of the time affected the ancient arts of spinning and dyeing in varied colours. Dress assumed the sombre hues of duffle-grey, brown, and blue. These dull hues were, in point of fact, due to the wretchedly dirty streets of the large towns, and the miry roads. Arthur Young notes the same thing as prevalent in Paris in Revolution times, and connects it with the hard riding and driving of the time. The gay dresses of an earlier age were adapted to Sedan chairs and State barges. The changes in progress toward the end of the century were the disuse of the blue bonnet and, at a much later period, knee breeches. In France, the latter were so much a mark of gentility, and the

long trousers that of the non-privileged labouring class, that at the Revolution the Jacobins called themselves "Sansculottes"—that is to say, those who discarded the aristocratic leg-gear for the workman's. The most marked change was the disappearance of the blue bonnet. At Laurencekirk, about 1770, a hatter from Edinburgh appeared on a Saturday; seeing in church but three hats besides his own, he made off on the Monday. There is now (1792), says the minister, hardly a single bonnet. At Symington, in Ayrshire, about the same date, young women blushed to be seen in the blue cloaks, red plaids, and plain caps, that were common within twenty years. Even the scarlet mantle, the mark of the farmer's daughter, is despised. The bonnet-makers of Kilmarnock have no trade now, and the young women are not to be seen at church and fair in a coat of their mother's spinning. Ramsay observes that throughout Menteith the rigid thrift that was a necessity of the time prevailed in the article of dress. The clothes of the family and servants were spun and dyed at home. Solid farmers had nothing better than a coat of grey or black *kelt*—that is to say, of black or white wool in its natural state, and spun by their wives. As this would not keep out the rain, twice or thrice in a lifetime they bought a greatcoat of English cloth. Both sexes had shirts of *plaiden*—a sort of coarse woollen, or of *harn*, a kind of coarse linen, but on holidays these had necks and sleeves of finer stuff. The English traveller, Lettice, in Ecclefechan at fair time, gives an interesting picture of the village as it must have met the eyes of the youthful Carlyle. The Scots bonnet and plaid surtout were worn by the men; the short jacket and petticoat of two colours, with a square, chequered wrapper or cloak, were worn by the women. The men's plaid was a thick stuff of small chequered blue or green on a white ground, and, unless in bad weather, it was drawn up round the body, or hung negligently over the left shoulder with no ungraceful air. The nice conduct of the plaid was, indeed, the chief outlet for male vanity. Mrs. Scott, of Wauchope, addressing Burns, says—

"Oh, gif I kened but whaur ye baide  
I'd send to you a marlèd plaid;  
'Twad haud your shouthers warm and braw,  
And douce at kirk or market shaw;  
Fra south as weel as north, my lad,  
A' honest Scotsmen lo'e the maud."

Burns' own dress, as described by William Clark, his man at Ellisland, was characteristic of the time. In cold weather the poet wore a black and white checked plaid round the shoulders. At home he usually wore a broad blue bonnet, blue or drab long-tailed coat, corduroy breeches, dark-blue stockings, and cootikens or gaiters. There was little extravagance then in foot gear. It had been universal to make the ordinary shoes at home. These were the *revlins*, still seen in Shetland, and so innocent of shape that they suited either foot. Even the shoes of Harry Cockburn, when a High School boy, were no better in this matter of fit, each requiring daily reversing to save wear. In the Highlands there was not a lad of fifteen but could make his own brogues. The labouring class generally dispensed with stockings and shoes, which, Lettice says, caused very ill-judged contempt on the part of English visitors, for the Englishman is apt to associate bare feet with the extreme of destitution. In Hoddam, Carlyle's parish, clogs were much worn in winter, and three cloggers figure among the village artists, as workmen are called in the "Statistical Account."

Burns was greatly pleased with any little novelty of female dress. Jean Armour was one of the first in Dumfries to appear in a gingham dress, then costly. Beauty of face was, indeed, not so attractive to him as a general air of health and vivacity, coupled with that neatness of coiffure which still lives in the peculiarly appreciative epithet, *snod*. A maiden found that, next to her eyes, the best dart in her quiver was her *cockernony*, or gathering up of the hair when *snooded* with a band or fillet, as among the Greeks. He thought David Allan the only artist that succeeded in genuine pastoral costume. "Independently of their Hogarthian humour, his etchings exhibit the character and costume of the Scottish peasantry with inimitable felicity." Allan faithfully depicts such an admirable sketch as this :—

"Roger kaims his hair, indeed, an' gaes richt snug  
Wi' ribbon knots at his blue bonnet lug,  
Whilk pensylie he wears a thocht ajee,  
And spreads his garters diced beneath the knee;  
He falds his o'erlay doon his breast wi' care,  
An' few gangs trigger to the kirk or fair."

"*Gentle Shepherd.*"

The dress of last century survived to within living memory. Dr. Gregor, the venerable and learned minister of Pitsligo, thus

described to me his mother's preparations for church:—"On her head she placed a skull-cap to keep the hair up, and over that a fine linen cap, lying quite flat, followed by a broad ribbon going round the head, and fastened behind. Over all came a band of thin cambric, drawn into a *ruching* on the top, and having a broad flat border, showing the hair on the edge. Her outer dress was a red cloak with a hood, and made of fine wool. Her ordinary errand-going cloak was a duffle or bluish-grey. His father at kirk and fair wore a long coat, with brass buttons, of bluish cloth, and, for a working dress, home-made clothes, with a smaller coat of home-spun wool. On all occasions he wore knee-breeches."

The improvements in agriculture, the rise of the Lanarkshire cotton trade, and the application of coal to iron-smelting, produced a complete revolution in the domestic economy of Scotland during the last quarter of the century. The change showed itself markedly in the increased use of butcher meat, wheaten bread, tea, and whisky. An old farmer told Ramsay that his father was, in his remembrance, the only tenant in Ochertyre that had a winter mart. The others generally used a few old ewes that would not sell or were likely to die. *Braxy*, the name given to such mutton, is still the general term for meat in Buchan. About 1760 not more than fifty beasts were killed in a year in Ayr, a town of 6,000 inhabitants. One Edinburgh lady had still her mart in Cockburn's youth, her custom being to begin at the head and finish with the tail. Inviting a friend to dine with her, she advised him to come in soon, as she was now at the rump. At Bonhill meat was only beginning to be used in 1792; at Largo labourers had no meat except at a birth or a marriage. All over it may be said that, at the close of the century, the rural population rarely had flesh in the pot. As fresh meat, visitors were treated to fowls so lean that southern strangers thought of carving them by using the breast-bone of the one to cut up the other. Pork was looked upon all over with the greatest aversion. In these days travellers noticed the absence of the cotter's pig, but admit that there was little for it to live on in the meagre establishments of the time. The general culture of the potato did more than anything else for the cotter's pig. At Aberdeen, and, again, in Galloway and Dumfries, there was a great trade in pork for the navy, but the staple was black cattle, which prevailed everywhere, almost to the total exclusion of sheep.

Anciently there had been two distinct varieties of sheep—in the north a small long-legged white variety with fine wool, and in the moors of Lanark, Teviotdale, and Galloway, the black-faced kind. The mutton of the latter was much superior, but the wool scanty and coarse. The flocks were very small, each croft carrying a few, so tender that they had to be housed at night most of the year. The heights were grazed by goats, and not till late in the century was sheep-farming introduced on any great scale. An Ayrshire man introduced sheep-farming into the Highlands near Luss, and it spread so fast as largely to depopulate the upland districts by evictions. At the same time sheep rapidly disappeared in lowland arable districts.

Fishing was but little indulged in, and then only in connection with crofter farming. Country people would not taste eels or pike; trout and salmon were much esteemed; of sea-fish, only the herring was much sought after, and then only when shoals came inshore. All the while the Dutch busses were reaping a rich harvest on our coasts, a state of matters lamented by Thomson in the "Seasons." On the east coast there was a great trade with London in lobsters and salmon—kippered, boiled, and preserved in ice.

The staple dinner dish was kail. Round every cottage was the kail yard, fenced by a low turf wall, and sheltered by an elder hedge. Little else but kail or open cabbage was grown in it; latterly such additions were made as gooseberry bushes, thyme, southernwood, balm, mint, and camomile. Water-kail or bare-foot broth—that is to say, without meat, was a Teutonic dish, for the Highlanders of old abominated the plant as fit only for goats. In default of "kitchen" or meat, were used butter, cheese, herring, or raw onions from Flanders. Broth was sometimes made of greens and grolls, which were oats stripped of the husks in the mill, for pot-barley was difficult to procure. In every cottage there used to be the knockin'-stane, a deep cup-like block, in which the barley was allowed to lie in water, and then it was beaten with a small mallet till it was unhusked. We owe the pot-barley mill to Fletcher of Saltoun, who had lived in Holland, and had seen it in use. He went back to Holland, taking with him a mill-wright, James Meikle. Meikle built the first mill at Saltoun, near Haddington, and for long enjoyed a monopoly of the trade. For forty years it was the only pot-barley mill in the United Kingdom or America. Various were the dishes made with kail, for it

was the mainstay both of dinner and supper. Burns praises its virtues in his "Epistle to M'Adam"—

" And when those legs to guid warm kail  
Wi' welcome canna bear me,  
A lee dyke-side, a sybow [onion] tail,  
And barley-scones shall cheer me."

Wheaten bread drove out the only other staple food, oatmeal cakes, just as the latter had superseded the still older barley, bear, and pease. In Menteith, tenants sat at table with their servants, and oatmeal porridge was thought a luxury among them, bearm meal being used. Wheat loaves, says Ramsay, are now commoner than oat cakes were formerly. In every house there was an iron girdle for baking cakes, Culross having long a monopoly of their manufacture. The "Jolly Beggars" were so merry that "wi' jumpin' and thumpin' the very girdle rang." The baker is modern. At Govan, in 1794, there was no baker, butcher, or public market of any kind. Loaf bread was supplied from Glasgow, the trouble of fetching it being taken out of the size of the loaf. About 1770 only two wheaten loaves came from Perth to two Auchterarder families weekly; "a baker now, 1794, sells £200 worth in the year."

The staple breakfast dish was porridge and milk, and for supper sowens. The Hallowe'en supper in Burns' poem is an invitation "till buttered sowens wi' fragrant lunt." To make sowens, the rough husk of the grain is taken, with some meal attached, and mixed with good meal. The mixture, called *sids*, is put in cold water to steep, and then into a big dish, with a perforated bottom to strain over another dish. This upper sieve or strainer is the *seisons*—that is to say, what *sies* or strains the sowens, hence the name. The *sids* are squeezed in the hand to wash the meal out and get the *good* in the liquor; the gluten remains at the bottom of the dish. Sowens are either drinking or boiling; the former, when newly made, is like thin pea-soup, and is put on the fire at once, but never allowed to boil. When it rises and is thickened, it is taken off and poured out. In olden times it was then drunk off, but, in later, sweetened with treacle first. Boiling sowens lay in the sowed bowie or barrel till it fermented and soured, then it was boiled to a thin porridge, and taken with milk. The glutinous lumps in it made it troublesome to sup. A minister heard his man in the garden helping himself to his "twal' hours" meals of sowens, and using very strong language, not a usual

occurrence with him, and under the circumstances shocking, for the sermon was on the anvil. The minister looked out, horrified, and rebuked John, who excused himself on the ground that it was hard to catch the sowens. The simple diet of those days may be judged from the dietary of the boys of Gordon's Hospital, Aberdeen. Bread and milk, oat and barley meal, and vegetables, formed the chief part of every day's fare. Animal food was seldom seen.

The position of the rural population was, if a healthy and moderately contented, certainly not a bright one. Burns speaks of the ceaseless toil of galley slaves that was the lot of his father, Gilbert, and himself. There was little hired labour outside each family, and not much demand for tradesmen. A considerable kirk-town might boast a smith, a millwright, a weaver, and a tailor. Time spared from field-work in summer was spent in long and arduous journeys to the peat moss to secure winter fuel. There was little facility for conveying coal far from the open sheuchs on the hillside, as the poor pits of those days were called. Deep workings were impossible at a time when the coals had to be carried on women's backs up a ladder fixed to the side of the shaft.

"The withered eld that up the winding shaft  
With trembling steps ascends her pitchy way;  
Her wrinkled cheeks with streaks of coom besmeared,  
And heavy burden on her feeble back."—Geo. Wallace.

The Government, too, was inhuman enough to tax sea-borne coal. The long winter nights were spent in making and mending plough graith, harness, flails, &c., as well as in knitting, at which the men were adepts. The women's work was never done. In summer the ewes were milked in *buchts* or folds for some weeks after the lambs left them. Dairying otherwise was but little practised on any but the most limited scale and slovenly fashion. In backward districts the gudewife even put a frog for luck into the *ream-bowie* (cream tub). Then the meal had often to be made by the quern. Spinning took up most of the spare time, and served not only to clothe the family but to earn some needful ready money. The primitive rock and reel, or distaff and spindle, has not yet become obsolete in the outer isles, but a wheel was then in most houses. A great step in advance was the introduction of the two-handed wheel, learnt from the Dutch. At Leslie, before 1770, it was unknown, but became general over the

Lowlands soon after. Knitting and spinning attained the greatest advance in Aberdeenshire, where these industries were eagerly engaged in by almost the whole population. Middlemen gave out yarn, and collected enormous quantities of stockings for export. A dearth at home or a war on the Continent greatly helped the trade.

Spinning was the great bond of social union in the hamlet, for at nightfall neighbour girls would drop in, each with her wheel, and pass the time in tale and talk. The tailor, if on his rounds, was a welcome gossip; and even the poor vagrant was not refused a corner, his supper, and a bed of pease-straw in the byre. Later on, the lads dropped in, sat or leaned on the deas, and joked and looked their loves in lumpish fashion. An escort home over the moor, and the privilege of carrying Jenny's wheel, were ample reward. This was called a *rockin*, as in the "Epistle to Lapraik," "On Fasten e'en we had a rockin." At Mossiel such social meetings were frequent. The old rock or distaff was portable, hence the phrase "going a rockin," and when the wheel took the place of the rock the expression was still used for such meetings. The courting customs were closely bound up therewith, and to this we owe "My Nannie O," "Mary Morrison," "Rigs o' Barley," &c.

Flax was grown on every farm, and the cotter servants were also entitled to so much lint-seed to sow for themselves. The lint-coble or pond for steeping the flax was also a necessary adjunct. The lint, thus grown and prepared, was made into yarn by the family, the girls being early taught to spin. In using the single wheel, the lint was pulled from the rock, and moistened between the thumb and forefinger. This constant use of saliva was blamed as a cause of the great prevalence of consumption. Coarse linen was woven by the village weaver into *harn* for shirts and bed coverlets. The latter was called *cannis*—that is to say, canvas (Lat., *cannabis*, hemp). A similar sheet was laid down to receive the grain when it was being threshed, hence the Buchan proverb, "We can thresh i' oor ain cannis."

We fail to realise the boon conferred upon us by the invention of lucifer matches, not perfected till the present generation. The old strike-a-light, still manufactured at Brandon, in Suffolk, required a flint, a steel, and a tinder-box. In Buchan the steel was called the flourish, or fleerish. Many persons still living have seen the flint, steel, and awm (alum) paper used by the *stane-knapper*

at the roadside to get a light for his pipe. For domestic purposes the tinder was kept in the tinder-box, which was in two parts—a box to hold the tinder and a lid to extinguish it, the latter sometimes arranged to serve as a candlestick. An improvement on the awm-paper was the spunk, or brimstone match, tipped with sulphur, and used to get a flame from the tinder. This was universal from 1800-50. In the olden days candles were taxed articles, and it was the duty of Burns, as an excise officer, to see that the tax was not evaded. He generally looked the other way, however, as when, passing through the kitchen one night at William Lorimer's, of Kennishall, where the gudewife was busy making candles, he merely remarked—"Faith, madam, ye're thrang the nicht," and passed into the parlour. There were two substitutes for candles. The one was the ancient oil lamp, the croosie (Fr. *creuset*), a triangular metal saucer with an upright hook at the base to be hung up by. There was an inner saucer, movable, to graduate the use of the oil. At the apex of the angle was the flame, coming from a wick made of the pith of rushes, which must be cut at full moon, as the flame was thought to wax and wane with the moon if cut at any other time. The other substitute for the candle was the bog can'le. It was made by splitting up the resinous logs of the primeval firs that are found embedded in the bogs. They were left to dry over the cruck at the fireside, which was the chain that held up the pot over the fire. The candlestick was called the *peer-man*, a stone with a hole in its centre, into which was fixed a pillar of wood about four feet high, and tipped with a cleft piece of iron into which the candle fitted. The nose of the candle was always turned to the door.

The appearance of the country folks reflected that of the general condition of the country. Topham says:—"One must be struck in every part of the country with the extreme ugliness of the lower orders." Such pictorial representations as we have of the time remind us of the Dutch pictures of peasant life. This state of matters was ascribed to the climate, and, certainly, agricultural improvements have worked vast changes. We hear constantly of ague, asthma, consumption, and rheumatism or *pains*, for which low damp houses, poor diet, working in peat mosses, and the like, were to blame. Sowing, draining, planting, road-making, and increased industry, have removed their efficient causes. Topham finds what he saw inconsistent with Rousseau's sentimental

theories and the fancied charms of life according to Nature. "Here," he says, "temperance and labour are in the extreme, yet, instead of ruddy cheeks, sprightly faces, and graceful figures, we find haggard looks, meagre complexions, and bodies weakened by fatigue and worn down by the inclemency of the season." Here is a vivid picture of the labouring poor from the "Twa Dogs":—

" A cotter howkin in a sheuch  
Wi' dirty stanes biggin a dyke,  
Barin' a quarry or sic-like,  
Himsel' a wife he thus sustains,  
A smytrie o' wee duddie weans,  
An' nocht but his han' darg to keep  
Them richt and ticht in thaik and raip."

Burns says of his father that, worn out by early hardship, he was unfit for labour. "The cheerless gloom of a hermit, with the unceasing moil of a galley slave, brought me to my 16th year," by which time he was doing the work of a grown man. Every one was seized with a craving for a bit of land, yet few had sufficient capital to make it do more than yield a bare subsistence, and this with the utmost thrift, and the labour of the entire family. Classes were not far apart, for all had reached a similar low level of comfort. For wage-earners, in the absence of manufactures and good markets, the conditions were little better. Till the last twenty-five years, says Ramsay, the ordinary farm-staff was a big man, a little, and a *pleghan* (*Gael.*, a small spade, paddle, or dibble)—that is to say, a lad to plough or thatch at odd times, with a boy to herd in the season, and a couple of maids. Even after 1760 wages were not above £3, and for women 20s. a year, with perquisites, in both cases, of food and clothing. A maid got a serge or drugget gown, two harn shifts, two pairs shoes, two pairs stockings, and an apron. There were few day labourers, and their general wage was sixpence a-day, with food. In Lauder, during the last decade, the poor brought up a family on £12 a year. At Ayr, a labourer, with wife and five children, lived on 5s. to 7s. a week. At Bathgate, families were reared on 5s. a week, with 2s. earned by the wife. The artisan was little better off—the day's wage of a wright, mason, or tailor, ranging from sixpence to a shilling, with food.

In spite of such a low scale of comfort, health was fairly well maintained, and there were many cases of extraordinary longevity.

Govan, in 1795, was a village of 224 families, and, though water was allowed to stagnate on each side of the high road that served as the only street, the people were healthy and lived long. At Forgan, in Fife, there lived a man over ninety on St. Fort, the estate of Colonel Lindsay. The colonel asked him one day how many lairds of St. Fort he had seen, when he replied, "Six; and I hope to see the seventh." "What! do you wish a change of lairds?" "Oh, no, but I suppose there would be no objection to the coming home of a young laird?" The colonel had lately married. At Montquhitter, Aberdeenshire, a neighbour condoled with Mary Crookshank, 99, on the loss of a daughter, and observed that she herself would soon follow. "Aye, what fey [doomed to die] token do 'ee see aboot me?"

Upon the whole, however, the population had increased but little, many parishes going back rather. Before the union of the crowns the population of Scotland was only half-a-million. By the end of the eighteenth century this had only reached a million and a-half. Edinburgh topped all the towns with 70,000; then followed Glasgow, 61,000; Dundee, 22,500. These were all that were over 20,000. More than half the population lived in hamlets of fewer than 300 souls. Yet there was a general complaint, familiar at the present day, that the villages and country districts were being depopulated through the increasing size of farms and the growth of factories.

Although wages were very low, the general possession of a bit of land, and the comparative independence of skilled labour for domestic wants, enabled most families to live on a moderate outlay. Prices of food were low from our point of view, though the difference in the spending power of money must be remembered. The following scale prevailed at Aberdeen, and fairly represents an average over the country:—Beef, 2d.-5d. a lb. (22 oz.); butter, 6d.-8d. (28 oz.); hen, 6d.-10d.; duck, do.; goose, 2s. 3d. At Inverness beef sold at 2d.-4d.; veal, 3d.-5d.; pork or mutton, 2d.-3d.; chickens, 3d.-4d. a pair; ducks, 1s. do.; eggs, 7 a penny; salmon, 1d.-1½d. a lb. But Inverness at that time represented the low-water mark in urban communities.

It is greatly to the credit of the people and the clergy that there was little pauperism and less crime. In Wigtown, and near highland districts, mendicancy was at its worst. "There were constant supplies from Ireland of poor emaciated creatures, whose very aspect excites compassion. Every week fresh cargoes reach

Portpatrick." Highland notions fostered begging, as it was considered unchristian to refuse help to God's poor. Elsewhere the clergy looked with disfavour on the threatened introduction of a poor law, and may likely depreciate the prevailing distress. Their poor were entirely dependent on the church-door collections. It was thought disgraceful that relief should thus fall virtually on tenants and craftsmen, as is the complaint of the Rev. W. Auld (Burns' "Daddy Auld") at Mauchline, for the non-resident heritors (a very numerous body) escaped altogether. "It is the poor in Scotland that maintain the poor." Dissenters also gave nothing either to the parish or to their own poor, all going to support their own separatist services. The sturdy independence of many is praised by the clergy. At Ayton the indigent were unwilling to be put upon the roll, though in real distress; and at Sorbie, in Wigtownshire, it was considered disgraceful to receive charity from the parish funds. Some attempts were made to found benefit societies, such as at Mauchline, where a friendly society had been set up in 1780, which, for a guinea on entry, gave 2s. a week to the disabled, and 3s. to the bed-ridden.

In those days of defective police it was fortunate that the law-abiding were in the vast majority. There were some exceptions. Eaglesham was over-run with gipsies, tinkers, and randy beggars, and there was no magistrate within four miles. The tinkers and horners of the uplands generally were a nuisance. As a rule, however, very many parishes report that there is not a doctor or lawyer within their bounds, and little need for either. Suicide was deemed a horrible crime. At Birse, Aberdeenshire, 1793, "one low-spirited wretch some years ago finished his life." Generally speaking the report of the ministers is, "No one capitally punished in this parish within living memory." Yet there must have been many discharged soldiers and sailors about, accustomed to violence. Government service, however, was extremely unpopular, and one who had enlisted was looked upon as thoroughly abandoned. The odious press-gang contributed to this feeling: it harried the fishing villages on the east coast. In war-time the men took to the hills, and left their families destitute, or clubbed together in boats' crews to pay for substitutes. The prisons were a disgrace to humanity. "Here" (at Cupar), says the minister, "our jail would be a heartbreak to Howard." Debtors' quarters, he tells us, were tolerably decent, but persons confined on suspicion of theft had the iron house, a dark, damp, vaulted dungeon, entirely of

stone, without a fire-place, or any, the most wretched accommodation. It was lit by irregular apertures, 9 inches square, with a slit on either side of 30 inches by 2. The circuit sat at Perth, spring and autumn, and prisoners had often to lie in such a place over the winter.

Much remains to complete the picture of the rural life of Scotland a hundred years ago—the interesting folk-lore, with its *freits* and quaint customs, not unmixed with superstition, that marked the various incidents of domestic life and the change of seasons; the various ills flesh then endured—smallpox, epilepsy, leprosy, insanity—with their cures; the health resorts, in the shape of holy wells and springs that took the place of the modern drug shop; the mirth of the people at fairs, New-year's Day, Handsel Monday, and the Sacrament, recalling the joyous life of pre-Reformation times; the dram-shops and drinking habits of all classes; the deplorable state of the roads, inns, bridges, and means of communication. In the larger world of Church and State would fall the relation of the people to the government in respect of irritating taxation and the severe repression of the Dundas despotism; the various and often whimsical forms of dissent and its sympathy with the poor and opposition to the prevailing Toryism that was living in daily terror of the spread of revolutionary ideas. Church and school preserved what little culture there was, but the former was hampered by all the serious inherent defects of Presbyterianism, and the latter, in spite of all that is said and boasted of our parochial schools, was in a state of such ignorance and contemptuous neglect as to be a disgrace to all parties concerned. One wonders, indeed, that so poor and backward a country made the material progress we can now observe; that modern Scotland could ever have made its world-wide triumphs in philosophy, theology, poetry, and general literary eminence, out of the miserable provision for teaching that existed a hundred years ago, is little short of miraculous.

SOURCES OF INFORMATION ON THE CONDITION OF RURAL  
SCOTLAND (1748-1800), MORE OR LESS CONTEMPORARY.

I.—HISTORICAL AND STATISTICAL.

“Statistical Account of Scotland.” Edited by Sir John Sinclair,  
21 vols., 1791-99.

[Contains reports by clergymen from all the parishes of Scotland (about 1,000 in number); begun 1790, vol. i. appeared May 25, 1791—a perfect storehouse of interesting and valuable information bearing on the economic condition of the country and the people. The editor promised a supplementary volume, giving an analysis of contents, with deductions therefrom, but this promise he never carried out.]

Wight—“Present State of Agriculture in Scotland,” 4 vols., 1778-84.

[Wight, of Ormiston, in the Lothians, on the suggestion of Lord Kames, was appointed in 1773 to prepare a survey for the Commissioners of the Annexed Estates (confiscated 1715-1745). He extended his survey to all the counties, and presented an admirable view of the contemporary condition of rural husbandry.]

“Communications to the Board of Agriculture—Reports by Counties,”  
9 vols., 1797-1818.

[These contain Colonel Fullarton’s excellent account of Ayrshire, with a complimentary allusion to Burns as a farmer.]

Ramsay, of Ochertyre (near Stirling)—“Scotland and the Scots in the  
18th Century,” 2 vols.

[Ramsay was the friend and correspondent of Burns. He presents a delightful view of contemporary life and manners.]

“Cockburn’s Memorials of his Time,” 1856.

[Henry Cockburn (1779-1854). The early portions of his reminiscences are extremely valuable, especially for the views of the upper strata of Edinburgh society.]

Carlyle (Alex.)—“Autobiography,” 1860.

[Minister of Inveresk (b. 1721, d. 1805). His book is not of much use as a picture of his times, he being too anxious to tell us the names of the big folks with whom he dined. His report on his parish in the “Statistical Account” is one of the best.]

“John Mill’s Diary,” 1740-1803. (Scot. Hist. Soc.)

[Minister of Dunrossness, in Shetland. Gives an admirable account of the contemporary effect of the stirring events of the time. His report on his parish in the “Statistical Account” is excellent.]

There are several histories of counties and parishes, such as Nimmo’s Stirlingshire, and Paterson’s Ayr and Wigtown, but they are too antiquarian in character to illustrate social life.

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"Glossary of the Banffshire Dialect," and "An Echo of the Olden Time,"  
by the Rev. Walter Gregor, D.D.

"The Past in the Present," by Sir Arthur Mitchell, M.D.

Minor Poems.—Keith's "Farmer's Ha'," "The Har'st Rig," Hector Macneill's "Will and Jean," Mayne's "Siller Gun," Gall's "Tint Quey," Wallace's "Prospect from the Hills of Fife," &c. These, in addition to their literary interest, afford graphic illustrations of rural life during the latter half of last century.

II.—OBSERVATIONS OF TRAVELLERS.

"Pococke's Tours in Scotland," 1747, 1750, 1760 (Scot. Hist. Soc.), 1887.

Gray (Thos.)—"Letters of the poet describing his short visits to  
Edinburgh, Perthshire, and Glasgow," 1764-5.

[Little close observation.]

Pennant—"Tours in Scotland," 1769-72; 3 vols., 1790.

[A scientific, intelligent, and well disposed visitor: his illustrations very good; might be called the discoverer of Staffa and Fingal's Cave.]

"Johnson's Journey to the Western Islands," 1773. 1798.

"Boswell's Tour to the Hebrides with Johnson." 1787.

[Not of much value in this connection.]

Topham—"Letters from Edinburgh," 1774-5. 1776.

[Observations of a very intelligent Englishman: most valuable.]

Heron—"Observations on a Journey through the West of Scotland,"  
2 vols., 1793.

Lettice—"Tour through Scotland." 1794.

Murray (Hon. Mrs.—a lady of Perthshire family)—"Guide to the Beauties  
of Scotland," 2 vols. 1799-1802.

[These last three works give excellent accounts of the state of the roads, the wretched ruins, and general appearance of the country and peasantry. Mrs. Murray went over most of the Highlands.]

Wordsworth (Dorothy)—"Recollections of a Tour in Scotland," 1803.

[A shrewdly observant and interesting account of the poet's famous visit, given by his sister. Coleridge accompanied them for a time.]

III.—ILLUSTRATED BOOKS.

Clerk, of Eldin—"Etchings of Views in Scotland," 1773-9.

Cordiner—"Antiquities of the North of Scotland," 1780.

[Minister of Banff, and pupil of Foulis, Glasgow Academy of Art. His views not so good as Pennant's.]

"The Gentle Shepherd," with David Allan's illustrations in aqua-tint,  
pub. by Foulis, 1788.

[Allan made his studies on the spot, of Habbie's Howe, the scene of the poem, in 1786-7. Burns greatly admired his plates, and was pleased with Thomson's plan to have his collection of songs, to which Burns so largely contributed, similarly illustrated, but this was never carried out. Allan, b. Alloa, 1744, d. 1796, was a pupil with Foulis, and studied in Italy.]

Grose—"Antiquities of Scotland," 2 vols., 1789.

"Views of Principal Towns in Scotland," 1797.

Forsyth—"Beauties of Scotland," illustrated, 5 vols., 1805.

Fraser (Minister of St. John's, Edinburgh)—"Kirk and Manse,"  
60 views, 1857.

"Geikie's Etchings," about 1820.

There are several illustrated editions of Burns, but none before 1800. Currie's "Life" (not illustrated) has an elaborate article on the condition of the Scottish peasantry. In it about as little light is given on the subject as Johnson's "Rasselas" gives on the natives of Abyssinia. Macintosh's "History of Civilisation in Scotland," 4 vols., 1891, is defective just at the point where we are most interested in the making of Modern Scotland. Of the antiquarian kind, there is nothing more suggestive than Sir Arthur Mitchell's Rhind Lectures, "The Past in the Present."

# TABLES SHOWING COST OF LIVING, WAGES, DISTRIBUTION OF POPULATION, &c.

## I.—MONIMAIL, FIFE—PURELY AGRICULTURAL.

	1750.	1790.
Beef, ... ..	2d. (lb. Dutch 22 oz.)	4d.
Mutton, ... ..	2d. "	4d.
Veal, ... ..	4d. "	7d.
Butter, ... ..	4d. "	8d.
Hens, ... ..	4d. ... ..	1s.
Salmon, ... ..	1d. and 1½d. (lb.)	5d.—6d.
Eggs, ... ..	1½d. and 2d. (doz.)	3d.—5d.
Day labourers earn ... ..	5d. ... ..	9d.—1s.
Master wright or mason, ... ..	1s. ... ..	1s. 3d.—1s. 6d.
Journeyman, ,, ... ..	8d. ... ..	1s.
Ploughmen (year), ... ..	{ £2—£2 10s. (2 pecks } meal weekly),	{ £6—£7.

II.—EXPENSES OF A DAY LABOURER, IN DUMFRIESSHIRE, WITH WIFE AND 4 CHILDREN; AND IN LOCHGELLY, FIFESHIRE, WITH 3 CHILDREN, 1793.

EXPENSES.

DUMFRIESSHIRE—	£	s.	d.	FIFESHIRE—	£	s.	d.
House rent, with kail yard, 1	0	0		House rent (hovel), with			
Fuel (peats), ...	0	6	0	kail yard, ...	0	13	0
Working jacket and				C als, with carriage, ...	1	0	0
breeches, ...	0	5	0	Clothing (man), ...	1	10	0
Two shirts, 6s.; clogs, 3s.;				„ (wife and children), 1	5	0	
2 pairs stockings, 2s.,	0	11	0	Worsted for mending,	0	7	0
Hat, 1s.; Handkerchief,				Soap for washing, ...	0	2	6
1s. 6d., ...	0	2	6	Shoes for family, ...	1	0	0
Petticoat, bedgown, shift,							
caps for wife, ...	0	9	0				
Pair stockings, 1s.; clogs,							
2s. 6d.; apron, 1s. 6d.;							
napkin, 1s. 6d., for wife,	0	6	6				
Shirt, 2s.; clogs, 2s.; stock-							
ings, 1s., for each of 4							
children, ...	1	0	0				
Other clothes for children,							
about ...	0	16	0				
Schooling, ...	0	10	0				
Two stones oatmeal weekly,				Two pecks oatmeal, at			
at 1s. 8d., ...	8	13	4	11½d., ...	4	19	8
Milk, 9d. weekly; butter,				Two pecks barley or pease,			
3d. weekly, ...	2	12	0	at 7d., ...	3	5	0
Salt, candles, thread, soap,				Six bolls potatoes, at 5s.,	1	10	0
sugar, tea, ...	0	13	0	Pot barley, 3d. a-week,	0	16	3
Tear and wear of Sunday				Milk, 4d. „	0	17	4
clothes, ...	0	10	0	Salt, cheese, butter, &c.,	0	12	6
	<u>£17</u>	<u>14</u>	<u>4</u>		<u>£17</u>	<u>18</u>	<u>3</u>

INCOME

	£	s.	d.		£	s.	d.
48 weeks' wages, at 6s.,	14	8	0	48 weeks' wages, at 6s.,	14	8	0
Wife's labour in harvest,	1	10	0	„ wife spinning,	3	12	0
Winter spinning, 1s. and							
1s. 6d. a-week, say,	2	5	0				
	<u>£18</u>	<u>3</u>	<u>0</u>		<u>£18</u>	<u>0</u>	<u>0</u>

## III.—COST OF LIVING IN A WEAVING VILLAGE NEAR PERTH, 1794.

Family—a weaver, his wife, three children (youngest an infant, eldest under five years).

## WEEKLY EXPENSES—

Three pecks oatmeal, two barley meal, ... ..	£0 3 8
Milk, salt, onions, and potatoes, ... ..	0 1 0
Butter, cheese, bacon, &c., ... ..	0 0 8
Soap, starch, blue, oil, ... ..	0 0 6
Thread, thrums, worsted, ... ..	0 0 1
	<hr/>
	£0 5 11
	<hr/>
Weekly Earnings—Man and wife working together, ... ..	£0 9 0
	<hr/>
Expenses for year, ... ..	£15 7 8
Earnings, ... ..	23 8 0
	<hr/>
Excess of earnings, ... ..	£8 0 4
	<hr/>

## ANNUAL EXPENSES—

Man's wear of a suit, 4s. 6d.; of a working jacket and breeches, 4s.; of a hat and handkerchief, 2s., ... ..	£0 10 6
Man's wear of two shirts, 8s.; of a pair of shoes and two pairs stockings, 9s., ... ..	0 17 0
Wife's wear of gown and petticoat, 5s.; two shifts, 6s. 6d.; two pairs shoes, 4s.; two aprons, 3s.; stockings, 1s. 6d.; handkerchiefs, caps, &c., 7s., ... ..	1 7 0
The children's wear, ... ..	1 1 0
Fuel, ... ..	0 12 0
Sickness and burial expenses, one year with another, ... ..	1 5 0
	<hr/>
	£5 12 6
	<hr/>

Balance after deducting annual expenses from excess of earnings, ... .. £2 7 10  
 Rent of house and garden, £1; met by produce of same (vegetables and potatoes).

## IV.—WAGES IN BARONY PARISH, GLASGOW, 1794.

	a-day.		a-week.
Labourers (winter), ... ..	10d.—1s.	Weaver, ... ..	10s.—14s.
„ (summer), 1s. 2d.—1s. 4d.			
	a-day (without food).		a-year.
Reapers (men), ... ..	1s. 4d.—1s. 6d.	Collier, 2s. 9d.—3s. a-day,	£30
„ (women), 1s.		Domestics (men), ... ..	£10
Expenses of labourer and family,		„ (women), ... ..	£3 5s.
£16 a-year.		Ploughmen, ... ..	£10—£12

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V.—WEEKLY EXPENSES OF AN ENGLISH VILLAGER, WITH WIFE AND FOUR CHILDREN.—From *Contemporary Review*, March, 1892.

Rent, ... ..	£0 2 0	Butter (1 lb.), ... ..	£0 1 0
Sick Club, ... ..	0 0 6	Milk, ... ..	0 1 0
Bread (8 lbs.), ... ..	0 3 0	Treacle, ... ..	0 0 3
Flour, ... ..	0 0 9	Salt, &c., ... ..	0 0 2
Meat (6 lbs.), ... ..	0 4 0	Light, Fuel, ... ..	0 2 0
Sugar (2 lbs.), ... ..	0 0 6	Clothes, &c., ... ..	0 2 8
Potatoes, ... ..	0 0 10	Repairs, &c., ... ..	0 2 8
Cheese (1 lb.), ... ..	0 0 8	Tools, Furniture, Sundries, ... ..	0 0 10
Tea ( $\frac{1}{4}$ lb.), ... ..	0 1 0		
			<u>£1 1 2</u>

VI.—COMPARATIVE ESTIMATE OF POPULATION OF LEADING TOWNS.

1791.	1891.	1791.	1891.
Edinburgh, ... size of Leith.		Ayr, ... size of Lanark.	
Glasgow, ... „ Greenock.		Kilmarnock, ... „ Selkirk.	
Dundee, ... „ Dunfermline.		Montrose, ... „ Saltcoats.	
Aberdeen, ... „ Inverness.		Dunfermline, ... „ Annan.	
Paisley, ... „ Hawick.		Arbroath, ... „ Ardrrossan.	
Perth, ... „ Airdrie.		Inverness, ... „ Renfrew.	
Greenock, ... „ Rutherglen.		Stirling, ... „ Girvan.	
Leith, ... „ Alloa.		Campbeltown, ... „ Cupar.	
Dumfries, ... „ St. Andrews.		Dalkeith, ... „ Crieff.	
Kirkcaldy, ... „ Stranraer.		Port-Glasgow, ... „ Oban.	

VII.—GROWTH OF TOWNS.

1792.	1892.	1792.	1892.
Edinburgh, 68,045 ...	261,261.	Ayr, 5,560 ...	24,798.
Glasgow, 61,743 ...	792,728.	Montrose, 5,194 ...	13,048.
Dundee, 22,500 ...	155,640.	Dunfermline, 5,192 ...	22,365.
Aberdeen, 20,067 ...	121,905.	Arbroath, 5,183 ...	22,960.
Paisley, 19,903 ...	66,427.	Inverness, 5,107 ...	19,214.
Perth, 19,500 ...	30,760.	Stirling, 5,000 ...	16,895.
Greenock, 15,000 ...	63,498.	Campbeltown, 5,000 ...	8,235.
Leith, 13,241 ...	69,696.	Dalkeith, 4,100 ...	7,300.
Dumfries, 6,902 ...	17,804.	Port-Glasgow, 4,036 ...	13,294.
Kirkcaldy, 6,356 ...	27,151.	Musselburgh, 4,015 ...	8,885.
Kilmarnock, 5,670 ...	27,959.	Brechin, 4,000 ...	8,955.

In respect of density, population one hundred years ago followed precisely the same lines as now. Of these 22 populous places (4,000 and upwards) the Forth and Clyde valleys (river and estuary) have each seven, the Tay (including all Forfar) has five, there are two north of the Grampians (Aberdeen and Inverness), one on the Solway (Dumfries), and none on the English border. Duns and Hawick, then the largest places there, had little over 2,000.

## VIII.—VILLAGE POPULATION, NOW PART OF A GREAT CITY.

## Population of Villages in Barony Parish, 1794.

Calton and Bridgeton, ...	6,695.	Parkhouse, ...	499.
Anderston, ...	3,900.	Camlachie, ...	977.
Cowcaddens and North		Parkhead, ...	678.
Woodside, ...	1,158.	Shettleston, ...	766.

One hundred years ago 55 per cent. of the population lived in hamlets of fewer than 300 inhabitants.

The rise of manufacturing industry towards the end of last century caused, to a marked degree, a redistribution of the population, a great increase in prices and in the use of luxuries, and a deterioration in public morals. New Lanark, where the cotton industry was founded in Scotland by David Dale and Robert Owen, was the scene of an interesting social experiment. The juvenile workers were boarded, and their diet was as follows :— Porridge and milk twice a day in summer ; sowens and milk in winter. Dinner—barley broth, with boiled beef (7 oz. a piece), for half the number, alternating with the other half, who got bread and cheese with the broth. Now and then pork was given, or herrings and potatoes. Work was from 6 a.m. to 7 p.m., with half-an-hour for breakfast, and an hour for dinner. The children had evening school till nine, and slept three in a bed.

GÖTTINGEN TITLE-PAGE.

DEMOCRITVS

ABDERRITA

DE ARTE

MAGNA,

*Sive de rebus naturalibus.*

Necnon Syneſii, & Pelagii, & Stepha-  
ni Alexandrini, & Michaelis Pſel-  
li in eundem commentaria.

*Dominico Pizimentiono Vibonenſi  
Interprete.*



PATAVIV  
Apud Simonem Galignanum  
MDLXXII





DEMOCRITVS

AB DERITA

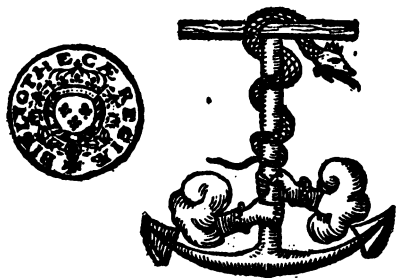
DE ARTE

MAGNA.

*Sive de rebus naturalibus.*

Nec non Synesii, & Pelagii, & Stephani  
Alexandrini, & Michaelis Psel-  
li in eundem commentaria.

*Dominico Pizimentione Vibonensi  
Interprete.*



PATAVINO  
Apud Simonem Galignanum  
M D LXXIII.

33395

IX.—*On the First Edition of the Chemical Writings of Democritus and Synesius*. Part III. By Professor JOHN FERGUSON, M.A., LL.D., F.S.A., F.S.A.Scot., F.C.S.

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[Read before the Society, 18th November, 1891.]

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(PLATE III.)

1. At the corresponding meeting last Session, 19th Nov., 1890, I communicated to the Society an account of a very rare copy in the University Library, Cambridge, of the Latin translation, by Pizimenti, of the chemical writings of Democritus and certain other Greek authors, printed at Padua in 1573. To the paper, since printed,<sup>1</sup> I have added a facsimile of the title page, and have pointed out that, from the unsymmetrical position of the middle I in the date, the date must have been altered from MDLXXII. to MDLXXIII. by the insertion of an additional I, subsequent to the original printing. I also drew the inference that, unless all the copies had been similarly altered, one might still be found bearing the date 1572.

2. On subsequent consideration it occurred to me that, if the date had been altered by the insertion of an extra I, it was improbable that the unsymmetricalness of its position would be the same in every copy, and I could not help observing that in the only other copy of the book I then knew, that at Göttingen, neither Beckmann nor Kopp had taken notice of such an obvious feature of the title page.

3. To confirm my view of the matter I wrote, so long ago as last February, to Professor Dziatzko, principal librarian at Göttingen, with a photograph of the title page of the Cambridge copy, and in reply to certain questions which I asked received a most courteous

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<sup>1</sup> *Proceedings* of the Philosophical Society of Glasgow, 1891, vol. XXII., p. 301, Postscript.

reply,<sup>2</sup> giving me complete information on the points required. The following is a translation of the parts in question :—

“ 1st. The two title pages agree exactly, except in the figure I in the date.

“ 2ndly. Under the initial A of ABDERITA (larger and placed somewhat obliquely) stands also in our copy an I, which had been scraped out before the A was printed over it.

“ 3rd. The three ones in our copy stand thus [with a sketch of their arrangement]. Obviously the centre type was not in the printing, but was afterwards inserted in the space between the other two by hand, which would come out differently in the different copies. The inserted I seems to be a *shade* smaller, the other figures are equal.”

4. It is plain from this that in the Göttingen copy the centre I occupies a different position relatively to the other two from what it does in the Cambridge copy. Of course, if the date had been originally printed MDLXXIII., it would have been the same in every copy. This was exactly the point that I was desirous of settling. Comparison of the two title pages shows that the middle I was inserted subsequent to the printing of the title page, and Professor Dziatzko, from what he says, has obviously arrived independently at the same conclusion. But just because in the Göttingen copy the symmetry happens to be fairly complete, the alteration of the date has escaped the notice both of Beckmann and Kopp, and one may question whether, without another copy for comparison, the alteration could have been easily detected in the Göttingen copy alone. To complete this part of the subject, I now intend to get, if possible, a photograph of the Göttingen copy, which will exhibit more distinctly than any amount of description the difference between it and the Cambridge copy.<sup>3</sup>

5. I have had recently other opportunities for investigating this question.

During a visit which I paid this last September to the Bibliothèque Nationale at Paris, I was gratified at finding another copy

<sup>2</sup> Dated: Königl. Universitäts-Bibliothek, Göttingen, Feb. 7, 1891.

<sup>3</sup> February, 1892. I have since got a photograph of the title page of the Göttingen copy, through the kindness of the authorities of the University Library there, from which a lithographic copy has been made. It requires no comment, and all that has to be done is to compare it with the facsimiles of the copies in Cambridge University Library and the Bibliothèque Nationale to see that the date is differently arranged. Though this facsimile is rather smaller than the original and the other two facsimiles, that does not affect the main point under discussion.

of this book, dated 1573, the title page of which I was very kindly allowed to have photographed for me by M. Dujardin, the well-known photo-engraver. From this a zincograph has been made by Messrs. Walker & Boutall, of Clifford's Inn, London, which enables the difference between it and the Cambridge copy to be displayed.

One difference is that the initial A in ABDERITA is considerably larger than that in the Cambridge copy, although, like it (and the Göttingen copy), it is placed obliquely so as to hide the I.

As for the date, the Paris copy also has the middle I misplaced, so that it resembles the Cambridge copy very closely: but careful examination shows—1st, an almost imperceptible difference in the spacing; and, 2nd, that the middle I is not of exactly the same length in the two copies.

By these facts the view is much corroborated that the original date was MDLXXII., but that it was altered to MDLXXIII. by hand, so that different copies exhibit different positions of the middle figure.

6. Since that visit my attention has been directed to the Catalogue<sup>4</sup> of the Library in the Barberini Palace at Rome, in which there are apparently two copies of the book, dated 1573. I have not as yet been able to obtain any description of these copies, but I hope not only to be able to lay an account of them before the Society, but to include photographs of the title-pages as well, so as to complete the series as far as I can.

7. There are thus five (?) copies of the book, three of which *certainly* (and I think it is reasonable to suppose that the other two as well) bear evidence of the fact that the date 1573 is an amended or altered one from 1572.

When, therefore, I argued seven years ago,<sup>5</sup> from the fact of my having found a copy of the Cologne edition of 1572, that there must be an Italian edition earlier than that, or at least as early, I was induced to do so from the improbability of a translation by an Italian being first published at Cologne, and that not as an independent work, but as a mere appendix to the quite different

<sup>4</sup> Index, 1681.

<sup>5</sup> *Proceedings* of the Philosophical Society of Glasgow, 1885, vol. XVI., p. 41, § 10.

work of Mizaldus, which had been published at Paris six years earlier. I had not had at that time the opportunity of comparing the Padua edition with that of Cologne, else I could have spoken with more certainty, and I did not anticipate that the Padua edition of 1573 would be itself one of the strongest pieces of evidence in support of the view I advanced.

8. A visit, however, to the Bibliothèque Ste. Geneviève at Paris set finally the whole question at rest, for there, at last, was forthcoming a copy of the Padua edition, dated 1572, and it was satisfactory to find that the possibility which I had suggested at the close of last year's paper,<sup>6</sup> of some copies having escaped alteration, had become a certainty by the discovery of one of them. Of the title page of this edition also I hope to have a photograph, so that it may be printed along with the present paper.<sup>7</sup>

9. At the conclusion of the first paper on this subject, I gave a list of nine editions, of which I had seen four, knew of one on reliable authority, and was very doubtful about the remaining four. The list as it now stands revised contains seven editions, all of which I have seen; the remaining two are still very doubtful. The lists are as follow:—

## 1884 List.

					Authorities.
1570 (?)...	Rome, (?)	...	...	...	Conring.
1572 ...	Cologne,	...	...	...	Ferguson.
1572 (?)...	Padua, (?)	...	...	...	Ducange.
1573 ...	Cologne (previously unknown),				Ferguson.
1573 ...	Padua, ...	...	...	...	Beckmann, Kopp.
1574 (?)...	Cologne, (?)	...	...	...	Reinesius, Conring.
1717 ...	Nürnberg (in Latin),	...	...	...	Ferguson.
1717 (?)...	Nürnberg (in German), (?)	...	...	...	Dufresnoy, Schmieder.
1869 ...	Braunschweig,	...	...	...	Dr. Kopp's reprint.

## 1891 List.

1. Padua, 1572,	...	Bibliothèque Ste. Geneviève, Paris.
2. Cologne, 1572,	...	Hunterian Library, } Glasgow.
3. " "	...	University Library, }
4. " "	...	University Library, Cambridge.
5. " "	...	New College, Oxford.
6. " "	...	Trinity College, Cambridge.
7. " "	...	Copy seen by Dr. Kopp.

<sup>6</sup> See above, § 1, Note <sup>1</sup>.

<sup>7</sup> June 1, 1892.—I have not succeeded as yet in getting this photograph.

- |         |                        |                                     |
|---------|------------------------|-------------------------------------|
| 8.      | Padua, 1573, ...       | ... University Library, Cambridge.  |
| 9.      | " " ...                | ... Bibliothèque Nationale.         |
| 10.     | " " ...                | ... University Library, Göttingen.  |
| 11, 12. | " " ...                | ... Barberini Library, Rome.        |
| 13.     | Cologne, 1573,         | ... British Museum.                 |
| 14.     | Cologne, 1574,         | ... University Library, Cambridge.  |
| 15.     | " " ...                | ... University Library, Aberdeen.   |
| 16.     | Nürnberg, 1717,        | ... Young Collection, Glasgow.      |
| 17.     | Braunschweig, 1869,... | Reprint in Kopp's <i>Beiträge</i> . |

I have still to see the edition of Rome, 1570, and of Nürnberg, 1717, in German.

10. No previous writer on the subject has seen more than one, or at most two of these editions which I have now described, and many of those who have mentioned the book at all have done so in an unsatisfactory manner, because they had seen no copies and took their descriptions from other writers.

The two chief authorities, for example, for the 1573 Padua edition, from personal examination, Beckmann and Dr. Kopp, denied the existence of an earlier dated edition, and went the length of marking as erroneous the statements of other writers who spoke of editions previous to that one.

The authorities for the different editions may be now briefly enumerated:—

The 1572 Padua edition is mentioned by Fabricius,<sup>8</sup> doubtfully by Ducange,<sup>9</sup> without any question by Mullach,<sup>10</sup> and descriptively by Gmelin.<sup>11</sup> Beckmann<sup>12</sup> says that Fabricius cannot have

<sup>8</sup> *Bibliotheca Græca*, Hamburgi, 1708, I., p. 809.

<sup>9</sup> "Editus dicitur Patavii anno 1572. nescio an & Græcè." *Index Auctorum Græcorum*, col. 25, at the end of the second volume of the *Glossarium ad Scriptores Mediæ & Infimæ Græcitatæ*. Lugduni, 1688, folio. In my former reference to Ducange's statement (*Proceedings*, Phil. Soc., Glasgow, 1885, vol. XVI., p. 42, § 10), I said that he could not tell whether it was in Greek or in Latin, and I was led to do so by Kopp's (*Beiträge zur Geschichte der Chemie*, Braunschweig, 1869, p. 113, Note 22) reading: "nescio an græcæ." Ducange's own reading, however, is different, and means that he was not sure if the Greek was published as well as the Latin.

<sup>10</sup> *Democriti Abderitæ Operum Fragmenta*, Berolini, 1843, p. 157 (compare p. 158). Mullach simply copies from Fabricius (*Bibl. Græca*, 1708, I., p. 809) without acknowledgment.

<sup>11</sup> *Geschichte der Chemie*, Göttingen, 1797, I., p. 21.

<sup>12</sup> *Beiträge zur Geschichte der Erfindungen*, Leipzig, 1792, III., p. 376, Note 29.

seen the book, as he does not give either the title or date correctly. The date is certainly correct; and as for the title, Fabricius, I think, was giving a description of the contents of the book, rather than the actual words of the title. Dr. Kopp agrees tacitly with this criticism of Beckmann's, which, all the same, is wrong.

The 1572 Cologne reprint is mentioned by Mercklin,<sup>13</sup> Fabricius,<sup>14</sup> by Lambeck<sup>15</sup> in his commentaries, and by Fuchs.<sup>16</sup> Kopp, who was in doubt about it in 1869, informed me afterwards that he had seen a copy.

The 1573 Padua edition is given by Fabricius,<sup>17</sup> by Reinesius,<sup>18</sup> in the *Beytrag*,<sup>19</sup> by Beckmann<sup>20</sup> (who has printed a careful account of it from the Göttingen copy), by Fuchs,<sup>21</sup> by S. F. G. Hoffmann,<sup>22</sup> Dufresnoy,<sup>23</sup> Brunet,<sup>24</sup> and Graesse,<sup>25</sup> by Hoefer,<sup>26</sup> by Reuven's,<sup>27</sup> by Sprengel,<sup>28</sup> by J. F. Gmelin,<sup>29</sup> by Schmieder,<sup>30</sup> by Kopp, and by Berthelot.<sup>31</sup>

<sup>13</sup> *Lindenius Renovatus*, Norimbergæ, 1686, p. 243.

<sup>14</sup> *Bibliotheca Græca*, Hamburgi, 1724, XII., p. 709.

<sup>15</sup> *Commentariorum . . . Liber Sextus*, Vindob., 1780, p. 383, quoted by Kopp, *Beyträge*, 1869, p. 111, note 13.

<sup>16</sup> *Repertorium der Chemischen Litteratur*, Jena u. Leipzig, 1806, p. 2.

<sup>17</sup> *Bibliotheca Græca*, Hamburgi, 1717, VIII., p. 232, Note 1. *Ibid.* 1724, XII., p. 709. Although Fabricius mentions this and the Cologne 1572 reprint together on p. 709, the discrepancy of date and difference of contents do not seem to have impressed him, from which I infer that he had not compared, or had not been able to compare, the two editions.

<sup>18</sup> Fabricius, *Bibliotheca Græca*, Hamburgi, 1724, XII., p. 750.

<sup>19</sup> *Beytrag zur Geschichte der höhern Chemie*, Leipzig, 1785, p. 578.

<sup>20</sup> *Beyträge zur Geschichte der Erfindungen*, Leipzig, 1792, III., p. 376, Note 29.

<sup>21</sup> *Repertorium der Chemischen Litteratur*, Jena u. Leipzig, 1806, p. 2.

<sup>22</sup> *Lexicon Bibliographicum*, Lipsiae, 1833, 8°, II., p. 9.

<sup>23</sup> *Histoire de la Philosophie Hermétique*, Paris, 1742, III., p. 146. This is under Democritus; but under Synesius (*Ibid.* p. 306) he quotes the 1572 edition.

<sup>24</sup> *Manuel du Libraire*, Paris, 1861, II., 584.

<sup>25</sup> *Trésor de Livres Rares et Précieux*, Dresde, 1861, II., 356.

<sup>26</sup> *Histoire de la Chimie*, 1842, I., p. 266, and 1866, I., p. 277.

<sup>27</sup> *Lettres à M. Letronne*, Leide, 1830, 4°, Troisième Lettre, p. 70, Note (c).

<sup>28</sup> *Histoire de la Médecine*, Paris, 1815, II., p. 158.

<sup>29</sup> *Geschichte der Chemie*, Göttingen, 1797, I., p. 314, Note m.

<sup>30</sup> *Geschichte der Alchemie*, Halle, 1832, p. 64.

<sup>31</sup> *Les Origines de l'Alchimie*, Paris, 1885, p. 105, &c., and *Collection des Anciens Alchimistes Grecs*, Paris, 1888, III. (Traduction), p. 378.

The 1573 Cologne edition is mentioned by no writer, except myself, and the first notice appeared in the *Proceedings* of this Society.<sup>32</sup>

The 1574 Cologne edition is mentioned by Borellius,<sup>33</sup> Mercklin,<sup>34</sup> and Reinesius,<sup>35</sup> and they are followed by a number of modern writers, Dufresnoy,<sup>36</sup> Fuchs,<sup>37</sup> Hoffmann,<sup>38</sup> Gmelin,<sup>39</sup> Schmieder,<sup>40</sup> and Graesse.<sup>41</sup> Conring<sup>42</sup> also quotes, incidentally, an edition of this date.

The Nürnberg edition, in Latin, is mentioned by Hoffmann,<sup>43</sup> Brunet,<sup>44</sup> and Graesse.<sup>45</sup>

The Brunswick reprint of 1869 is contained in Dr. Kopp's *Beiträge*, and is accessible to everyone.

It is singular that Borrichius, so far as I have observed, makes no reference to any of the editions of Pizimenti's translation, although he himself devoted so much attention to the Greek alchemists. Morhof,<sup>46</sup> on the other hand, though he mentions Pizimenti's translation, and speaks both of the Padua edition and that annexed to Mizaldus, gives no date for either. Apparently he had no copy at hand.

11. The two editions still wanting are—first, that of Rome, 1570, mentioned by Conring,<sup>47</sup> who probably founded his statement on the date of the dedication. I think it hardly probable

<sup>32</sup> *Proceedings* of the Philosophical Society of Glasgow, 1885, vol. XVI., p. 40, § 9.

<sup>33</sup> *Bibliotheca Chimica*, Paris, 1654, p. 75; Heidelbergæ, 1656, p. 71.

<sup>34</sup> *Lindenius Renovatus*, Norimbergæ, 1686, p. 243.

<sup>35</sup> Fabricius, *Bibliotheca Græca*, Hamburgi, 1724, XII., p. 749.

<sup>36</sup> *Histoire de la Philosophie Hermetique*, Paris, 1742, III., p. 147, 306.

<sup>37</sup> *Repertorium der Chemischen Literatur*, Jena u. Leipzig, 1806, p. 2.

<sup>38</sup> *Lexicon Bibliographicum*, Lipsiæ, 1833, II., p. 9.

<sup>39</sup> *Geschichte der Chemie*, Göttingen, 1797, I., p. 314, Note o. Gmelin, however, mentions it in connection with Pelagius.

<sup>40</sup> *Geschichte der Alchemie*, Halle, 1832, p. 64.

<sup>41</sup> *Trésor de Livres Rares et Précieux*, 1861, Dresde, II., p. 356.

<sup>42</sup> *De Hermetica Medicina*, Helmeſtadii, 1648, p. 27; 1669, p. 29.

<sup>43</sup> *Lexicon Bibliographicum*, Lipsiæ, 1833, p. 9.

<sup>44</sup> *Manuel du Libraire*, Paris, 1861, II., p. 584.

<sup>45</sup> *Trésor de Livres Rares et Précieux*, 1861, Dresde, II., p. 356.

<sup>46</sup> *Polyhistor*, Lubecæ, 1714, tom. II., lib. II., pars I., cap. VII., § 6; tom. I., lib. I., cap. XI., § 34. See also tom. II., lib. I., cap. V., § 1, where he speaks of Venice as the place of printing; "Si rectè memini," he adds. But Padua was the place.

<sup>47</sup> *De Hermetica Medicina*, Helmeſtadii 1648, p. 27; 1669, p. 29.

that there is an edition of that date. The circumstances mentioned below as to the printing of the 1572 edition at Padua seem to me adverse to such an edition. The other edition is that in German, Nürnberg, 1717. It is mentioned by Dufresnoy,<sup>48</sup> and by Schmieder.<sup>49</sup> I am entirely doubtful about this edition. It is possible that a Latin and German translation should be published in the same year, or even simultaneously in the same year, at the same place, and by the same or by different people; but while I have seen the Latin edition,<sup>50</sup> I have not seen the German, or any account of it, except by Dufresnoy and Schmieder, who do not always excel in accuracy, and who on this occasion have possibly been misled, as I said before.<sup>51</sup> At the same time, I should myself quite miss the full benefit of the bibliographic lesson that this whole subject conveys, if I were to be so rash as to assert that a 1570 edition of Rome, or a 1717 German translation, either did not or could not exist. I have given some reasons for strongly doubting their existence, but a copy of either may turn up any day, and stultify all hypotheses, however plausible.

12. As far, however, as a 1717 German translation is concerned, I think the following facts settle its non-existence :—

- 1°. A German translation of the chemical writings of the Abbot Synesius by Roth-Scholtz was published at Nürnberg in 1718, by the heirs of Joh. Dan. Tauber, along with the works (also in German) of Sendivogius. On the last page of Synesius' tract there is a small list of works to be had from the same publishers, and in that list is Democritus' *De Rebus Sacris*, in *Latin*.
- 2°. In 1720 (first edition 1718) Roth-Scholtz published an edition in Latin of the chemical works of Rivinus and of Vigani, at Nürnberg, by Tauber's heirs. In separate lists of Tauber's books contained in this edition the *German* version of Synesius is mentioned twice, but of Democritus' *De Rebus Sacris* only the *Latin* edition is advertised.
- 3°. In 1727 (second edition 1735) Tauber's heirs at Nürnberg published Roth-Scholtz's *Bibliotheca Chemica, oder Catalogus von Chymischen*

<sup>48</sup> *Histoire de la Philosophie Hermetique*, Paris, 1742, III., p. 147.

<sup>49</sup> *Geschichte der Alchemie*, Halle, 1832, p. 65.

<sup>50</sup> *Proceedings of the Philosophical Society of Glasgow*, 1885, vol. XVI., p. 43, § 13.

<sup>51</sup> *Proceedings of the Philosophical Society of Glasgow*, 1885, vol. XVI., p. 43, § 13, p. 45, § 16.

*Büchern*. On p. 54 appears: Democritus abderyta græcus de Rebus sacris . . . Norimbergæ, 1717; the Latin edition formerly described by me,<sup>52</sup> but not a single syllable about a German version.

If there had been a German translation of Democritus in 1717, published by Tauber's heirs, it would surely have been mentioned in some one of his advertisements, like the Latin edition. It might, of course, have been printed at Nürnberg by some other firm, but there is not a tittle of evidence in support of such a perfectly gratuitous assumption. Until, therefore, a copy of a German translation, published at Nürnberg in 1717, either by Tauber's heirs or some one else, has been actually seen, described, and the place where it exists specified, I must refuse to accept the statements of Dufresnoy and Schmieder.

13. Although this investigation has been confined entirely to the Latin translation of the Greek alchemical authors, it would be an unpardonable omission if no notice were taken of the most important contribution that has been recently made to the subject by the publication of the original Greek text itself. This is contained in the edition of the Greek Alchemists, printed from the finest of all the manuscripts,<sup>53</sup> that preserved in St. Mark's Library at Venice, edited by M. Berthelot, and published in Paris in 1888, in 3 vols., 4°. From this one can now see with what accuracy and completeness Pizimenti did the work of translation from the MS. which came to his hands by a Greek from Corfu; that, however, belongs to a different department of the subject, into which I do not intend at present to enter, as I may have an opportunity of doing so elsewhere.

14. I may now, however, give a detailed view of the contents of Pizimenti's translation:—

a 1, the title.

a 2 r to a 5 r, numbered fol. 2 r to f. 5 r, Pizimenti's address or preface to Cardinal Antonius Perrenottus. It ends: Datum Romæ. Calend. Septemb. M.D.LXX.<sup>54</sup>

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<sup>52</sup> *Proceedings* of the Philosophical Society of Glasgow, 1885, vol. XVI., p. 43, § 13.

<sup>53</sup> For a list of these MSS., thirty in all, reference may be made to my address on the subject when President of the Chemical Section of this Society in 1876. See *Proceedings*, X., p. 373.

<sup>54</sup> Though addressed to different persons, this preface is the same in the Padua, 1572, 1573, and Cologne, 1572, 1573, 1574 editions, with certain Vol. XXIII.

- Sig. a 5 v, or f. 5 v: Ex Rebus Natvra- | libvs, Et Mysticis | Democriti. |  
Ends b 3 (misprinted 5) r, or f. 11 r.
- Sig. b 3 v, or f. 11 v: Dioscoro Sacer- | doti Magni Serapi- | dis in  
Alexandria | Deo Favente. | Synesivs Philosophvs | S.P.D. |  
Ends c 2 r, or f. 18 r.
- Sig. c 2 v, or f. 18 v: Pelagii Philosophi | De Eadem Magna | Arte. |  
Ends c 7 r, or f. 23 r.
- What follows is not contained in the Cologne reprints.
- Sig. c 7 r, or f. 23 r: Stephani Alexandrini | Oecumenici Philosophi,  
& Magistri | Magne huius Artis Auri confi- | ciendi, Actio prima. |  
Dominico Pizimentio | Interprete. |
- Sig. d 1 v, f. 25 v, Actio secunda.
- Sig. d 6 r, f. 30 r: Eivsdem Stephani Epistola | ad Theodorum. |
- Sig. d 7 r, f. 31 r: Eivsdem Stephani De Ma- | teriali Mundo Deo  
faunte, | Actio tertia. |
- Sig. e 2 r, f. 34 r: Eivsdem Stephani In Id, Qvod | ad operationem  
facit, diuina bene | ficentia, Actio quarta. |
- Sig. e 7 r, f. 39 r: Eivsdem Stephani In Hvivs | artis opus Deo  
faunte. | Actio quinta. |
- Sig. f 2 r, f. 42 r: Eivsdem Stephani Deo | faunte, Actio sexta. |
- Sig. f 8 r, f. 48 r: Eivsdem Stephani Philosophi | Deo faunte, Actio  
septima. |
- Sig. g 5 v, f. 53 v (misnumbered f. 29): Eiusdem Stephani oecumenici  
philosophi | actio octava de huius artis sectione. |
- Sig. h 1 r, f. 57 r: Eiusdem Stephani philosophi ad Heraclium | Regem,  
ope diuina, actio nona. |
- Sig. i 1 r, f. 65 r: Michaelis Pselli Epistola | ad Xiphilinum Patri-  
archam. De Auri | conficiendi ratione, | Dominico Pizimentio |  
Vibonensi Interprete. |
- Ends i 6 v, f. 70 v, and after the text comes the licence in Italian.

15. Pizimenti's translation is dedicated by himself to Cardinal Antonius Perrenottus, and is dated Rome, Sept. 1, 1570. He concludes in saying that, if this work is agreeable, the Cardinal

exceptions, detailed in §§ 15, 17. I have noted also the following various readings:—

PATAV., 1572, 1573.	COLON., 1572, 1573, 1574.
f. 2 r, line 14, 15, longè, la-   reſ;	f. 214 r, line 16, longè lateſ;
f. 2 r, line 18, 19, referun-   tur	f. 214 r, line 21, referuntur : 1572.
	f. 214 r, line 21, referuatur ; 1573, 1574.
f. 5 r, line 7, ὁμοτροφὸν ἀπολλωνος	f. 217 v, line 28-9, omotrophon A-   pollonos
f. 5 r, line 10, δοτορ εαΟν Græcè	f. 218 r, line 4, dotor eaon Græ-   cè, 1572.
	f. 218 r, line 4, dotor eaō Græ-   cè, 1573, 1574.

may hope soon for a translation of the Commentaries on Democritus of Olympiodorus and others.<sup>55</sup> Olympiodorus and the others would, in fact, be contained in the original MS. he had, of which, however, he published only the authors above mentioned. Apparently Pizimenti never carried his translations any further, for Leo Allatius, who, at a much later date, 1661 or thereabouts (Kopp, *Beiträge*, p. 248, 249), meditated an edition of the Greek alchemists in the Vatican Library, gave a list of those he meant to publish, and enumerated those of which a translation had been made by Pizimenti. The list comprises only those mentioned above, so that Leo Allatius knew of no more.

16. But even from Pizimenti's own translation one work seems to have been omitted from the printed edition.

The work as it stands concludes with the licence. It is in Italian, and runs as follows:—

Io fra Massimiano da Crema, ho ueduto il | presente libro di carte  
83. nel quale sono De- | mocrito, Synesio, & Pelagio stampati, &  
Stef- | fano Alessandrino con Michele Psello, & O- | stane scritti à  
penna, & non in ho trovato, che | repugni alla fede Catholica. |

Idem qui supra Fr. Maximianus | Inq. Paduæ. |

I, Frater Maximianus da Crema, have seen the present book of 83 leaves, in which are Democritus, Synesius, and Pelagius, printed, and Stephanus Alexandrinus with Michael Psellus and Ostanus in manuscript (or written by pen), and have not seen anything therein opposed to the Catholic faith.

(Signed) Fra. Maximianus, Inq. Paduæ.

From the printed edition Ostanus has been omitted. This licence seems to me to be very curious, and to throw some light on the history of the book, though most unfortunately it has no date. But it is certainly remarkable that when the licence was drawn out the officer, or inspector, or *inquisitor*, had submitted to him a book partly in print, partly in MS.

The printed portion—assuming that it is the Padua edition he saw, and not a Roman one of 1570 or thereby—containing Democritus, Synesius, and Pelagius, occupies the leaves 5 verso to 23 recto; the MS. portion occupies, after printing, leaves 23

<sup>55</sup> Vale, & si hæc tibi non ingrata | fuisse significaueris, quæ, ut Hieronymo Fagiolo | uiro humanissimo, ac mecum summa familiarita- | te coniunctissimo petenti gratificarer, latina face | re uolui Olympiodori & aliorum commentaria in | eundem Democritum propediem expecta. | Datum Romæ. Calend. Septemb. M.D.LXX. |

recto to 70 verso, and contains only Stephanus and Psellus, Ostanes not having been printed. The last two leaves of the sheet are blank.

17. On comparing the Padua edition of 1573 with Birckmann's Cologne edition, either of 1572, 1573, or 1574 (for in this respect they are all alike), there are three things that are specially noteworthy :—

1°. Birckmann's edition contains Democritus, Synesius, and Pelagius, only, not Stephanus and Psellus.

2°. Pizimenti's preface or dedication is addressed, not to Perrenottus, but to Joannes Metellus Sequanus.

3°. This dedication is identical with that in the Padua edition, even to the date, Rome, Sept. 1, 1570, except at the very close. Instead of Pizimenti promising to send Olympiodorus and the others, he is made to say that the dedicatee may soon look for the commentaries of Stephanus Alexandrinus, Olympiodorus, and Pelagius.

*Pelagius* is, I suspect, a misprint for *Psellus*, because Pelagius was already printed.

It is plain from this that Birckmann had no copy of Stephanus Alexandrinus, which is contained in the Padua edition.

Birckmann, or whoever it was who wrote the preface to the 1572 edition of Mizaldus, says that, when he was half through the printing of Mizaldus, Sequanus sent him the Latin translation of Democritus, Synesius, and Pelagius, which, in compliance with Sequanus' advice, and as intrinsically appropriate, he had added on to the edition. This must have been prior to March 1st, 1572, the date of the preface.

Apparently, therefore, in reprinting Pizimenti's dedication, Sequanus' name was coolly substituted for Perrenottus' (which misled me formerly,<sup>56</sup> before I had seen the Padua edition), and the end of the dedication<sup>57</sup> was also altered so as to conceal the absence of Stephanus Alexandrinus and Psellus, and make appear as if they were coming shortly. Either, however, Sequanus never

<sup>56</sup> *Proceedings*, 1885, vol. XVI., p. 42, § 10.

<sup>57</sup> The dedication concludes thus in Birckmann's edition (1572, f. 218) :—  
"Vale, & si hæc tibi non ingrata fuisse significaueris, quæ, vt Hieronymo Fagiolo viro humanissimo : ac mecum summa familiaritate coniunctissimo, petenti, gratificarer, latina facere volui : Stephani Alexandrini, Olympiodori, & Pelagii cōmentaria, in eundem Democritum propediem expecta. Datum, Romæ. Calend. Septemb. M.D.LXX." This should be compared with the conclusion in the Padua edition, as given in § 15, Note <sup>55</sup>.

sent the finished printed edition of 1572, or else Birckmann was unable or did not think it worth while to reprint Stephanus and the rest.

18. The question, therefore, arises, what was the *copy* from which Birckmann printed? was it manuscript, or was it the printed Padua edition? If the former, Sequanus must have got a copy somehow from Pizimenti, and, in that case, one should hardly expect Pizimenti to give him a copy of the dedication to Perrenottus with permission to have it dedicated to himself.

It is, however, a remarkable coincidence that the portion printed by Birckmann should not only tally with the first 23 leaves of the Padua edition, but that this should be exactly the portion which was in print when Maximianus penned his licence.

It is plausible, therefore, to infer that Sequanus got possession of this printed portion, dedication and all, and sent it on to Birckmann, either himself making the alterations in the dedication to suit the circumstances, or getting or leaving Birckmann to make them.

In this latter case this portion at least of the Padua edition must have been printed before March 1st, 1572, the date of Birckmann's preface. Here it seems to me is additional evidence from the very facts that at first sight seemed to contradict it, and which originated this whole investigation, that there must have been an edition of a book by an Italian in Italy before one which appeared at Cologne as a mere addendum, and an accidental one, too, to another book. Even before I saw the copy dated 1572, I was convinced, by a comparison of the Cambridge copy with Birckmann's 1572 edition, that the former, though apparently dated 1573, was in reality the earlier. I am now more strongly persuaded of that fact than ever.

19. There still remains another and more difficult problem, of which at present I can offer no solution satisfactory to myself, that is—Why was the date altered from 1572 to 1573 in the Padua edition? One explanation that occurred to me was that the book had been printed: title page, with the date 1572; dedication and text as far as f. 23, *i.e.*, to the end of Pelagius (which is practically the first three sheets, *viz.*, a, b, and c), but was stopped at that point on account of some difficulty or informality about the licence, or possibly that it was printing without a licence at all. This would explain the peculiar and

minute specification in the licence of both print and manuscript. If the delay caused by this had been sufficiently protracted, the printing might have run on into the following year, in which case, the title page being already printed, all that could be done was to insert an extra I. Though the Ste. Geneviève 1572 copy contains the same licence as the others that creates no difficulty, for it is simply a copy which has escaped having the date altered.

All this is mere speculation, for there may have been no difficulty about the licence at all. Plenty of other reasons suggest themselves : there may have been a strike in the printing office, or there may have been a fire, or the type might have been required in a hurry for another book, and Stephanus Alexandrinus would have to wait, or political disturbances may have hindered the printer. I have looked in the chronologies to see if Padua was the scene of any commotion in 1572, but without success. Very likely it was none of these, and the only reason for changing the date was to pass off a year-old book as newly issued from the press ; or perhaps there was a defect which involved the cancelling of a leaf or sheet. To test this would involve a word-for-word comparison of a 1573 copy with that of 1572. This I have not had an opportunity of doing, and I doubt if there would be any result.

I frankly admit my inability at present to set this question at rest, and I must leave it over for future enquiry.

20. My conclusion, in the meantime, is this :—

Pizimenti's translation was *begun* to be printed at Padua in 1572. The first portion of this reached Cologne before March 1st, 1572, in time to be added to Birckmann's Mizaldus. The Padua edition was finished in 1572, or possibly not till 1573. At any rate, in the majority of copies the date 1572 of the title page (which seems to have been printed at once as part of the first sheet) was changed to 1573.

In 1573 Birckmann printed a new edition, and in 1574 the rest of it was issued with altered date only.

The book then disappeared till 1717, when it was printed in Latin at Nürnberg.

Kopp reprinted the translation of Democritus only in 1869.

Finally, Berthelot printed the Greek text, for the first time, in 1888.

I have seen all these editions. If I should come across the edition of Rome, 1570, or the German translation of 1717, I shall, I hope, be able to describe them to the Society, for then the list would be complete. The Roman edition is very doubtful ; I

do not think there is one. The German translation is, of course, possible; up to the present I have met with no copy, and the results of all my investigations are antagonistic to it.

21. I never anticipated that the list would extend as it has done. When the excessive and almost unaccountable rarity of every one of the editions is considered, it was improbable that they should have been, after all, so attainable as they have proved to be. Of the different copies enumerated in § 9 I have seen all except Nos. 6, 9, 10, and 11.

I am only too glad, at this resting-place in the investigation, to acknowledge with my best thanks the help and goodwill I have received from the librarians of the different libraries at home and on the continent, and from personal friends, without which this investigation could not have been made so complete even as it is.

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[October 1, 1892.—Since the preceding was written I have ascertained that in the Bibliothèque Mazarine at Paris there is a copy of an edition of Democritus *De Arte Magna*, by Pizimenti, printed at Padua in 1570, in 4°. I have not as yet seen it, and am therefore unable to say what it contains, or what light it may throw on the points that are still doubtful. There is no mention anywhere of a Padua edition of this date, for though Conring gives the date 1570, the place he specifies is Rome. Hitherto I have been doubtful about Conring's statement, but the undoubted existence of a Padua edition of 1570 makes the possibility of an edition printed at Rome in the same year much greater than before. I hope before long to lay before the Society the results of my examination of this quite unforeseen addition to the material of the research.]

#### ERRATUM.

§ 21, line 6, *for* Nos. 6, 9, 10, and 11, *read* Nos. 7, 10, 11, and 12.

X.—*The Origin of the Faust Legend*.\* By ALEXANDER TILLE,  
Ph.D., Lecturer on German in the University of Glasgow and  
Queen Margaret College.

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[Read before the Society, 29th February, 1892.]

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GENERALLY, it is no grateful task to inquire into the origin of a legend. The most of the popular tales which have an interest for us reach back to the oldest times—spring from conceptions of the world and mankind that we do not know, under primitive conditions also quite unknown to us, and which we are scarcely able to imagine. But even their hidden source sometimes makes them remarkable. On the one hand, it provokes the inquisitive mind; on the other, it very easily leads the imagination to daring combinations and reckless speculations, to which, of course, all doors are open by the nature of the subject. At the best, the result is that we find certain traditions to have arisen from certain wants of human nature, and, since these are changing every century, this does not mean very much.

It is quite a different thing with the Faust legend. This is no story of *prehistoric* periods, for which it would be necessary to consult palæontological science, or which has even a direct and proved relationship to the whole world of Teutonic gods; but it takes rise before our eyes in a century comparatively well educated, and about which we possess a great number of literary documents, contemporaneously with one of the most powerful mental movements that ever have excited the West of Europe—the religious reformation of the sixteenth century.

And there is even more than this. Its tradition does not originate in the cottages of poor and uneducated people, where darkest superstition and narrow-mindedness are at home, but among well-educated men, and even scholars, who are, or at least should be, the leaders of mental progress and criticism. It is connected with

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\* A Communication from the Philological Section.

the life of the most outstanding men of the sixteenth century in Germany, and even the great reformer, Dr. Martin Luther, and his learned friend, Philip Melanchthon, are touched by it; at least, the latter very likely knew the man who gave the main impulse to the development of the legend.

The history of the evolution of the Faust legend is to be sought for in *literary* sources. The searcher is nowhere compelled to complete, by the help of tales still living among people of the present time, what he finds. It is more the task of history, of literature, than of mythology, palæontology, or folk-lore. Of course, the folk-lore—the marvellous tales which go from one nation to another, and are propagated from generation to generation,—superstitious views, and the inclination of uneducated people to a supernatural contemplation of the world, stand in the back-ground. We have not to do with these, however, but with the fragments of them which, by contemporaries, are fixed in a literary form.

Deep thinking and difficult mental problems, which we are inclined to connect with the character of Faust after numerous poets have treated, deepened, and enlarged the subject, are far away from its *origin*.

Its cradle is elsewhere, among dissolute fellows, who squander to-day what yesterday they acquired by fraud; who do not quite *steal*, but whose conscience is not narrowed by too many ethical scruples; who enjoy life wherever there is something to be enjoyed; and who live in the most miserable condition, if misfortune once touches them. It is in the middle of the folk-life of the sixteenth century, with its indefinite belief in the marvellous world, created by the imagination of past centuries, its curious wants and desires, and their easy satisfaction; and yet in immediate contact with the most mentally advanced people of the nation, who, as true sons of their own times, were enveloped in superstition deeper than the rudest peasant of to-day in a remote village among the mountains.

Besides, the legend is nourished by that odd, anxious, and desperate religious suspense and fright which distinguishes the sixteenth century from all others. Although rooted in the most ancient popular beliefs, it yet borrows its form from the most modern theological science—a strange mixture of national character, religious belief, superstition, knowledge, fashion, cheating, humour, and pleasure in the wonderful and inexplicable.

This is the Faust legend of the sixteenth century up to its first literary composition. In the sixteenth century it passes through three stages.

A historical personage—a vagabond named George Sabellicus—travels through Germany, practises all sorts of sorceries according to the belief of his times, and revives the memory of an old character of folk-lore, a magician called Faust, “the Merry One,” pretending to be his successor, or even this character himself.

About the year 1541 this vagrant dies, and now a second stage of the legend begins. His character grows and grows. All sorts of drolleries, deceits, tricks, and boastings, which were previously told of other magicians and scholars, are now credited to *him*. In order to explain the magical power that he is supposed to possess, people connect him with the devil, and at last describe him as having entered into genuine league with the evil one.

In 1587 all this, hovering freely in the popular mind, is fused, by an uneducated but not ungifted man, into a whole, and subordinated to the thought that Faust sells his soul to the devil for knowledge, power, and riches. This is done in the first German popular version of the Faust legend, which appeared in the autumn of 1587 at Frankfurt on the Main.

This evening we have only to deal with the first two periods which I have named—the first being from 1506 till 1541, the second from 1541 to 1587;—for within these periods we shall find the true origin of the Faust legend.

In the sixth century Christianity had come to Germany, and since Gregory the Great the Roman Catholic priesthood had earnestly tried to absorb into the new religion the useful elements of the old German mythology. All the exploits which the priesthood and the songs related of the old gods were now conferred upon Christian saints. In the place of Wodan were put Saint Martin and other characters of the Christian legend. In the place of Donar (the Scandinavian Thor, to which Thursday owes its name), Peter and Christopher; in the place of Berchta and Holda, the Virgin Mary. But even after this process of absorption had gone on some hundred years, many relics of the old religion still remained in the minds of the common people. As old Christianity was far from thinking that the ancient gods of the Teutonic religions did not really exist, they were explained to be wicked spirits, demons, “Unholde,” who belonged to the realm of the evil deity. In most cases the large variety of great and

small characteristics which each one of the old gods united in himself were too much to be attributed to a single saint. Besides, the disintegration of the mythology of the priests and the songs was facilitated by the rudeness of the demonology of the common people. Different qualities of one deity became separate individuals. In this way Wodan, the old god of heaven, from whose name Wednesday is derived, lived on in the characters of Saint Martin, Saint Nicolas, Charlemagne, Frederic Barbarossa, and other heroes, as a monarch and a warrior; while in Hackelbärend, the Wild Huntsman, the Wode of North Germany, and Knecht Ruprecht (the English "Father Christmas"), he reappears as a defender of law and patron of home. And as a powerful magician he reappears, perhaps, in a character that is found familiar to the popular mind only at the beginning of the sixteenth century, but is very probably far older, that of the traditional magician Faust.

The time has passed when German and Scandinavian mythology were considered identical, and mythologists thought themselves authorised to claim everything that is told in the artificial poetry of the Eddas as common Teutonic and, therefore, German property. But there is a certain analogy between German and Scandinavian myth. In Scandinavia, Odin, the god of heaven, who, with his wonderful cloak, let me say, is known only in the northern part of Germany by his name Wodan, has also been turned into different persons. In the legend of Hadding, King of Denmark, as it is told by Saxo Grammaticus, a Danish author of the thirteenth century,\* the magic cloak is the property of the highest of the gods. He comes to the assistance of his favourite Hadding, who has been overcome in battle, puts him on his horse, wraps him in his cloak, and conducts him home through the air.

Four hundred years later the Scandinavians perceived the god to be a human magician. Olaus Magnus† says:—"Othinus, the greatest and oldest of the magicians, once conducted Hading, King of Denmark, who had been the sport of wonderful magic powers, and who for a long time had been kept far from his relations, on his horse over the wide sea back into his kingdom, covered by a cloak, through which he was not allowed to look."

Until the beginning of the sixteenth century we do not learn anything about a magician of the German popular belief called

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\*I., 12.

† *Gentium Septentrionalium Historiae Breviarium*, 1652, Ludg. Bas. III., 18.

Faust. Only in a well known English collection of anecdotes of the middle ages, "the *Gesta Romanorum*," a character appears that perhaps is connected with him—*Fortunatus*, the happy possessor of a magic hat. The name "*Faustus*," probably like "*Fortunatus*" is of Latin origin, and means "the Merry One." The word was used as a proper name in Latin comparatively early, but its wearers until the sixteenth century have nothing to do with the Faust legend.

Besides this Latin name there is a German one, *Faust*—that is to say, "clenched fist," a family name somewhat widely spread in Germany. The word was understood in this sense when a coat of arms was given to the magician thirty years after his death, which accordingly shows a clenched fist. In the later marionette play, *Faust's* servant, *Kaspar*, evidently understands his master's name in the same sense. How many people bore the name of *Faust* at that time we can see from the numerous matriculations of *Fausts* in German Universities. Yet the name of *our Faust* is to be understood in the Latin sense. He is called "the Merry One," just as *Odin*, in the Scandinavian mythology, is called *Oski* (that is to say, the ideal or perfect one), originally the same word as English "wish" or German "*wunsch*," which means "possessed of all accomplishments," and, therefore, naturally happy or merry.

Even at that period we understand little more about *Faust* than that he was a magician travelling through the country, supposed to be immensely wise, and able to perform the most wonderful enchantments. He who was *Faust* could call himself quite fairly "*Philosophus philosophorum*."

The circumstances through which this knowledge has come to us are quite curious. In the beginning of the sixteenth century it occurred to a young swindler, a "*scholasticus vagus*" or "*vagans*," one of that group of vagabonds among whom it was an honourable boast not even to have stolen a goose, to add the name of that celebrated magician to his own, and afterwards to pretend to be this wonder-worker himself. And he has succeeded.

The young vagabond was called, or called himself, *Georgius Sabellicus*. Whether that was really his family name or not can no longer be proved. He appears first in 1506 in a small town of Northern Germany, called *Gelnhausen*. There he declared publicly before a large body of people that his knowledge and his memory were so great that, if all the works of *Plato* and *Aristotle* were lost, he knew them so completely by heart that he, a second

Ezra, could restore them unassisted. But it does not seem that he felt himself quite sure of this faculty. For when, during his residence there, a well-known scholar of this time, Johann Tritheim, Abbot of the Benedictine Monastery of Saint Jacob, in Würzburg, rested in this town on a journey, he made himself scarce very quickly. But he sent the abbot his visiting card, which contained the words: "Magister Georgius Sabellicus, Faustus junior, fons necromanticorum, astrologus, magus secundus, chiromanticus, agromanticus, pyromanticus, in hydra arte secundus."

He called himself master of arts, but that he certainly was not. This was a piece of vain boasting, like the "Faustus junior" and all the other titles by which he claims to be the next after Faust in all magical arts. He seems to have been afraid of Tritheim, who, among the lower classes, was supposed, too, not to be very far from sorcery. For at the end of the same year, when our Sabellicus paid a visit to Würzburg, Tritheim's residence, he chose a moment when the abbot was absent, and boasted that he could perform the miracles of Jesus as often as anybody wished him to do so, and said that they were not at all astonishing.

In March, 1507, he finally came to Creuznach, declared himself to be the greatest master of alchemy, and, by the help of a very well-known knight and protector of the Reformers, Franz von Sickingen, he got the situation of a schoolmaster, which happened to be vacant in that city. What he taught the children is not known, but he was not very successful. Very soon he committed a great crime, and escaped punishment only by a speedy flight, and thought it best to keep out of the way for some years.\*

For six years we do not hear anything about him. Only in 1513 he appears again in Erfurt, which is not far from Creuznach.

The University of Erfurt was then the centre of the study of ancient Greek and Latin science, the so-called Humanities. The soul of these studies, Conrad Mudt, was a great friend of Reuchlin and Melancthon, and even Luther praised him for his remarkable learning. This Conrad Mudt, or as he called himself, according to the custom of his times, Mutianus Rufus, sitting one day in an inn, heard the vagabond Sabellicus talking and boasting near him, but he did not think it worth his while to expose such

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\* Joannis Trithemii, Abbatis Spanhemensis *Epistolarum familiarium libri duo*, Hagenoae, 1536, pp. 312-314.

a fellow. He had got on a good way in his bluster. Not only had he changed the comparatively modest name of Georgius Sabellicus, Faustus junior, into plain "Georgius Faustus," but had added to this the title "demigod of Heidelberg," by which probably he wished to pretend that he had been a student, or even a great scholar, of that celebrated University. \*

But no sooner does he come in sight than he disappears again, perhaps because Franz von Sickingen was still alive, and he was afraid of him. Again fifteen years pass without his giving a sign of life. Only in 1528, five years after Sickingen's death, we find him in Ingolstadt in circumstances little agreeable, namely, in conflict with the police. Again his title has increased. Previously he called himself magister, now he calls himself and is called *Doctor Jörg Faust von Heidelberg*. On a journey he had come there, found a sufficient number of admirers, and earned some money. What illegality he committed this time is unknown, but it is known that his behaviour offended the authorities, and he was ordered to leave the town and spend his money elsewhere. He was compelled to swear that he would not take revenge for this banishment. We shall now see that his assumed University degrees were a swindle. At that time all University men, students and graduates alike, were under the jurisdiction of the Universities, and if Sabellicus had been entitled to the protection of the University the police could not have banished him. †

Not very different was his lot in Wittenberg, the most famous University town of that time, the centre of the Reformation. Luther and Melancthon were professors there. Here he only escaped with difficulty the bailiffs whom the Duke Johann the Constant had sent to catch him. He is said to have had a similar experience at Nürnberg. There he was sitting in an inn when he scented danger; he pretended to be too hot, rose from dinner, paid his bill, and went out. No sooner was he in the open air when the police entered the room to take him.

But he was not the man to be frightened by adventures like these. He went on gaily from town to town, everywhere boasting of his secret powers. If he was not successful at one place, he was at another. He was a dissolute and licentious fellow, who more

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\* Tentzel, *Supplementum Historiae Gothanae*, Gena. I., p. 95.

† 1872 and 1873, *Oberbairisches Archiv für vater ländische Geschichte*, p. 336.

than once came very near losing his life through some love affair.\*

When, in 1527, the armies of the Emperor Charles the Fifth won victories in Italy, he boasted that they were won by the help of his magic powers. Where he carried things too far, he had to give "leg-bail"; where he kept himself within the limits of what was credible in his time, he was rather successful. And these limits were pretty wide.

We can scarcely realise to-day on how low a stage the most prominent and best-educated men of that time stood in respect to belief in magic, ghosts, astrology, and so on. We cannot even except the *Reformers*. Luther believed himself to be always surrounded by a host of actual visible devils. According to his "Table Talk,"† he not only believed in the possibility of a written bargain with the Evil One, but that such a bargain had really been made between a student of his and Satan. He knew our Sabellicus-Faustus by name at least, and once mentions him in his "Table Talk."‡ Melanchthon believed in celestial prognostics given by comets, and when in 1539 one was seen, he wrote to a friend that some tyrants would probably be removed by it.§ Ghosts he believed he had seen himself.|| That men could be changed into wolves was credible to him.¶ Lunatics he believed to be possessed by evil spirits.\*\* He forbade the students of Wittenberg to bathe in the Elbe, because ghosts had been seen there dangerous to bathing people.†† When his friend Camerarius translated into Latin a Greek work about celestial wonders, he wrote a preface for it. Calvin also believed in witches and magicians, and thought they partly tried to injure other people, partly to get revelations from the devil.

In 1523 Franz von Sickingen was dead, and in 1535 Sabellicus got fuller scope for his works and boastings, for in that year a great German scholar died, who was believed to possess great magic power, and who had a dog—in whose body the devil was supposed to dwell—Cornelius Agrippa of Nettesheim. In many respects our swindler could now fill his place in the popular belief.

\* Manlius, *Locorum Communium Collectanea*, 1563, pp. 38, 39.

† Ed. by Auri faber 1556, leaf 16\* ; ed. by Stangwald, 1603, leaf 3 ; ed. by Selnecker, 1581, leaf 3.

‡ 24, 100.

§ *Corpus Reformatorum*, 1809, 3499.

|| *De anima*.

¶ *Corp. Ref.*, 1809, 6661, p. 718.

\*\* *Corp. Ref.*, 1809, 5190.

†† *Corp. Ref.*, 1704.

Although it is not quite certain whether Melanchthon knew the vagabond personally, yet it is very probable, and not at all impossible. Often enough strangers came to Wittenberg, who abused the credulity and good-nature of the professor in the most shameless way, and played off a number of hoaxes upon him, to awaken his sympathy. \* So it is quite probable that a vagabond visited him, calling himself Faust, and telling him that he was half a fellow-countryman, to get some money from him. As a report of a little later time, probably based on Melanchthon's own words, tells,† the man said his native town was a small place, named Knittlingen, or, as the story says, Kundling, near Melanchthon's home, Bretten, in the Palatinate. He said that he had studied the magic art at the University of Krakaw. Very likely it is only through a mistake of the reporter that he gives Faust's christian name as Johannes instead of Georgius, as Sabellicus commonly called himself. But another part of this story is quite clearly false. In Krakow there was never a professorship of magic art, and, up to that time, no Faust and no Sabellicus had matriculated there.

It was no wonder if he found belief in such circles, even independently of his claim to be the old magician Faust, with his gift of foretelling and his enchantments, which were performed by his own power, and on which, as long as he lived, no one thought he was helped by any evil spirit. Of a bargain with the devil, moreover, there is nothing said at all.

If he had not been successful at the University of Ingolstadt, fortune was kind to him now at Würzburg, where Reuchlin had lectured, who refused to take a chair at Wittenberg, and where previously his enemy Tritheim had been staying. At that time Würzburg was also a circle of Humanists, first among whom was the provost of the cathedral, Moritz von Hutten.

In the year 1534 an expedition to Venezuela was undertaken from Germany, led by the younger brother of Moritz—Philipp von Hutten, who was murdered by the Spaniards in 1546. About 1539 he sent to Germany to have his horoscope drawn, and we find that this was done by Faustus. Though Faustus was probably well paid for it, he prophesied nothing but misfortune. And the year 1540 was actually such a bad one for Philipp von Hutten

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\* *Corpus Reformatorum*, 1809, 5731.

† *Johann Manlius, Locorum Communium Collectanea*, 1563, p. 38, 39.

that, in the beginning of 1541, he wrote home from Cora, in Venezuela, saying he had been so unlucky that it was plain the philosopher Faust had prophesied correctly, for they had passed a very bad year. \*

But this superstitious belief in Faust's performances was not universal. There were critical people too. Among them was an Italian physician of Worms, by name Philipp Beghardi, who, in 1539, wrote that many persons had been deceived by this Faust. He had not exactly *stolen*, but had *taken*, money wherever he could get it, and professed to be that old magician Faust.

In the north-east, the middle, and the south-west of Germany, we meet with Sabellicus-Faust at different times. He seems to have travelled through the country in all directions, on foot and on horseback, apparently often in splendour, trying to enter University circles, and boasting of his Humanistic learning; and again, if fortune proved unkind, in dirt and poverty—now a wonderful physician and learned humanist, full of pretensions; now a ragged, begging impostor.

Once more he appears—this time at Basel, in what year cannot exactly be said. There he dined in the big collegium, and gave the cook some rare birds that came from no one knew where. Probably he only wanted to make a show. A superstitious theologian, who was present at the dinner, tells us so later.†

About 1539 Sabellicus drew a horoscope. In the same year the above-mentioned Italian physician speaks of him as still alive. Not long afterwards he died,—in some extraordinary way it would seem, perhaps making a mistake with some chemical experiment, or being secretly assassinated. So far as we can follow his life up to the year 1539, it bears the appearance of real history. Nothing that his contemporaries tell of him rouses a suspicion of miraculous embellishment or intentional falsification. Their belief in him, and their hatred of him, are arguments of equal weight for the historical truth of his character.

What is astonishing in him is only his boasting. Nothing really impossible is told of him. But all this is now changed at a stroke. No sooner has he closed his eyes than his character begins to grow, and it very soon attains to something enormous and gruesome; and as the legend, with its tendrils always green, climbs upwards on its tree, serious actions and bright drolleries,

\* Meusel, Litt. Hist. Mag., 1785.

† Johannes Gast, Sermones Convivales, Basileae, 1543, 2, 280, 81.

jokes and deceits, are attributed to him, which the middle ages told of other persons, and some of which have their origin in the East. He becomes the centre of many wonderful and magic tales which were living in the memory of the time, and the popular fancy forms for itself an image of him that might *well* fascinate the minds of his contemporaries, and even of the two following centuries.

This further development does not take place all at once, but only slowly. The Reformation of the sixteenth century had abolished the belief in the intercession of the Virgin Mary and the so-called saints with the good Christian God, and this act had intensely increased the power of the evil deity. For while heretofore the Virgin Mary and a thousand saints had worked against the devil, now he had to fight only with the three persons of the Trinity. From the year 1530 Satan's power began to grow, and every year people became more afraid of him. After 1545 a whole literature about him arises in Germany. Whatever people found wrong in history or in their own lives, he got the credit of. Under these circumstances, it was not surprising that they connected the vagabond Sabellicus, or, as he is now always called, Faustus, with him, and that this connection grew closer and closer, until finally they ascribed all his supernatural powers to the assistance of the Prince of Darkness.

The first marvellous event told of the celebrated magician is his death. The earliest account of it dates from the year 1548. He is found in a book of the theologian, Johannes Gast, the same who met Faust at Basel. He tells, from hearsay, that the devil strangled the magician, and that his corpse lay on the bier with its face downwards, although they turned it five times on its back. At the same time Faust is brought into relationship with the devil in his lifetime. The superstitious theologian has also heard, and believes, that his horse and his dog, like the horse and the dog of Cornelius Agrippa of Nettesheim, were devils, who could perform all sorts of tasks, and that the dog sometimes assumed the form of a servant, and brought him food. He knows, besides all this, another story, based on a widespread belief of the middle ages, namely, that Faust has power over spirits—beings which were supposed to live in the air. This was told before of another vagrant, and of the Monastery of St. Diesenberg.\* Here it is

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\* Zimmernsche Chronik, III., 529.

first attributed to Faust. He comes into a monastery to sleep for the night. He asks for good wine, and they give him bad. In revenge, he sends a noisy ghost, who frightens, and finally expels the monks, and who reappears whenever a monk ventures to return.

About ten years later the reports of the dead swindler become more numerous. In 1561 the legend changes the actual circumstances so much that it describes Faust as having come from the University of Salamanca, as he himself had told that he came from Krakow.

In the year 1548, two years after Luther's death, a student, named Johannes Menlin Ornamentsbachensis, matriculated at Wittenberg. For a few years he studied there under Melanchthon, and, after the latter's death in 1560, he published a collection of extracts from his and other learned men's lectures and conversation. The book appeared in 1563, and in it Melanchthon speaks of being acquainted with a Faust, and tells what he has heard about him. If this is really based on a conversation with Melanchthon, it cannot have taken place before 1548, for in that year Menlin, or, as he called himself, Manlius, saw the professor for the first time.

Thus ten years have passed since Gast's account, and the legend has been growing all the time. There is no longer any doubt about the devil dwelling in Faust's dog. But they have come into a still closer relationship. The legend concerning Simon Magus is now attributed to him, that he had announced in Venice he would fly to heaven. The devil is said to have actually lifted him, but let him fall again, so that he was nearly killed. His death is described with far more detail than by Gast.

On the last day of his life, Faust is sitting very melancholy in a village inn, in the Dukedom of Würtemberg. The innkeeper asks why he is so sad. Faust only replies: "*Do not be frightened to-night.*" He goes to bed, and all is quiet till midnight; but at midnight the house is violently shaken, and everybody is terrified. Next morning Faust does not appear, and as he has not left his chamber by the middle of the day, the landlord enters it. He sees a terrible sight. Faust has been thrown out of bed, his neck is broken and his head twisted round, so that the face looks backward. This is how the devil has killed him.

A well-known German "*Chronique Scandaleuse*" of the time, written by a nobleman between 1563 and 1566,\* places the death of Faust in 1539, and says that he was killed at a very old age in Staufen, in Breisgau, by an evil spirit, whom, when he was alive, he had called his brother-in-law. Here is repeated, with a little variation, the legend of the noisy spirit, and it is localised in the Monastery of Lûxheim, in the Palatinate. But a new detail is added. He has left his books to the holder of the Domain of Staufen. Many people have afterwards tried to obtain them; but the chronicle sagely observes that they would have been a troublesome and unlucky possession.

The legend of Faust continues to grow. During the following decades we find his name very often mentioned. In books on the most varied subjects we meet with his name, generally used as a terrifying example, but occasionally with the fear expressed that the report of his deeds may incite others to imitate him. His fate occupies people's thoughts; he becomes a common subject of conversation; a coat of arms is invented for him.

Whatever had formerly been told of Albertus Magnus, Agrippa of Nettesheim, Schrammhans and Peter Schneider, George Baumann and Jakob von Liechtenberg, whether serious actions, drolleries, or tricks and impostures, begin now to be credited to Faust. Most authors repeat the stories of their predecessors, adding new elements, so that the legend grows and shoots forth ever-new branches and leaves. For the most part the statements of Manlius are repeated, since they rest upon Melanchthon's authority.

Thus the physician-in-ordinary of William of Cleves, and disciple of Cornelius Agrippa, John Weier, of Grave in Brabant, employed the legend, along with other stories, in the third edition of his book, † which he wrote in defence of the poor women who at that time were burned as witches in all parts of Germany. Weier has also heard that Faust called Satan his brother-in-law, and he tells how Faust once took a melancholy-looking man with a black beard for his friend from the infernal regions, looking at his feet to see if he had the well-known crooked claws.

Two other stories which are now attributed to Faust are of a different sort. One is of a bad joke which he plays with a clergy-

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\* *Zimmernsche Chronik*, III., 529.

† *De Præstigiis Daemonum*, 1563; 2nd ed., 1566; 3rd ed., 1568.

man, and it is very likely historical. The other goes to prove the danger of communicating with the spirit world when one has not the needful power over it. Once on his travels he is taken and imprisoned at Battenburg, near Grave, on the Maas, in the neighbourhood of Weier's home. He cultivates a friendship with the chaplain who has to watch him, and who treats him too kindly, and Faust, on leaving the prison, advises him to take arsenic as a specific for removing his beard without a razor. The chaplain rubs his face, with the result that not only the beard comes off but the skin also. Weier knows the damaged man, who has told him the story himself.

Another time a schoolmaster at Goslar had learned from Faust how to get Satan into a bottle. One day he goes into the forest to conjure up the devil—that is to say, by the aid of a magic formula, to compel him to appear. But he makes a mistake with the formula, and so the devil, instead of appearing to him in a tolerable shape, comes in a dreadful aspect, with flaming eyes, hooked nose, a boar's tusk, and the cheeks of a cat. The schoolmaster falls down in a fit, and when he comes to himself has lost the power of speech, which he does not regain for a year.

This anecdote marks a very important division in the development of the Faust legend. It is the first story which connects Faust, though indirectly, with the conjuration of the devil, which afterwards played so momentous a part in the legend, and, in a true sense, fixed its character.

Very soon the legend is enlarged to a whole *circle* of legends concerning Faust's deeds and sufferings. This is done in the year 1585 in a book of Hermann Witekind of Neuenrade, in Westfalen, who wrote under the *nom de plume*, Augustin Lercheimer von Steinfeld. He had studied at Wittenberg, and knew Melanchthon, who interested himself in him afterwards. In 1561 he went to Heidelberg, and later, was a professor there. He died in 1603. He was an enlightened, liberal man, and attacked especially the trials of witches, saying the poor women ought rather to be taken to the physician or the sacristan than before the magistrate. His book is entitled "Christian Consideration and Exhortation on Sorcery."\* The various stories are not found at one and the same place, but within a few chapters. These are no historical authority. That which perhaps is historical

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\* Christlich bedencken und erjnnernng von Zauberey, 1585; 2nd ed., Frankfurt, 1586.

in them is taken from Menlin, whom the author knows and believes in absolutely. The statement of Menlin about Kundling as Faust's native place, he converts, quite rightly, into Knittlingen, and mentions likewise the intended imprisonment of the magician by the Duke John the Constant. But already at that place the adorning legend begins its work. Faust does not escape the danger by natural means, but is warned by his spirit.

Of far greater moment is another new feature which surrounds, as by a frame, all that the Faust legend has embraced up to that time. It does not change very much of Faust's character. He remains, what he was before, the dissolute vagabond, who everywhere plays wicked tricks. But now a point is rendered conspicuous, of which we have hitherto only had hints. Gast and Menlin gave Faust a devil hidden in a dog, the *Chronicles of Gimmern* and *Weier* say he called Satan his brother-in-law. Now the legend develops Faust's relation to a higher power, and says he had made a bargain with the devil, and at once—quite precisely—a bargain for twenty-four years, during which the evil one should serve him, after which Faust's soul become his. \* Once, he says, Faust hesitated in his purpose, but then the devil threatened him so terribly that he assigned himself again to hell. † After the end of this space of time he was killed by the devil in a terrible way. ‡

That is the frame into which all Faust-stories are to be inserted, the number of which increases more and more. But they are not yet inserted in *Lercheimer*. The bargain with the devil is a story among others which, with one exception, are not influenced by this.

The story of the noisy spirit, which in the Faust legend appears at first in *Gast*, has here a somewhat different form. Faust does not send the spirit into an inhospitable monastery, but—very significantly of the increase of the religious contents of the legend—to a pious old man, who tries to convert him. But—significantly also—in opposition to the older form, belief conquers unbelief. Faust sends the spirit into the bed-room of the old man in order to terrify him. But the old man expels him by mocking at him for his apostacy from the good God; for devils are very tender in their feelings, and very easily hurt. The end is that the spirit returns to Faust very much ashamed, and without having been successful.

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\* Chapter 16.

† Chapter 19.

‡ Chapter 16.

Among the great number of anecdotes which Lercheimer relates about all sorts of magicians, there are four which he is the first to tell of Faust.

The first originates in Menlin's report that Melanchthon knew Faustus, and attributes a trick to him that was formerly told of other men.\* The before-mentioned Chronicle of Zimmern † that he gave a great dinner without preparing anything. One hour before it began, in a marvellous manner, he took away all the dishes he needed from the table of the King of France, and put them before his guests. Being once scolded by Melanchthon because of his godlessness, Faust threatens to do the same with him, and cause all his pots with the food in the kitchen to fly up the chimney, so that he should have nothing to eat with his guests. But as Melanchthon does not care for his threatening and despises him, he does not perform his purpose.‡

Of the same time a hunting trick of his is told. At Wittenberg he teaches an acquaintance what he must do in order that, whenever he wants to catch a hare and goes into the forest for it, one may run into his hands.§

Also Lercheimer mentions another trick, told formerly of many other magicians and non-magicians, the unhappy flying of Faust at Venice (of which Menlin told first). But besides, he tells another one that apparently is performed in Germany. Once at Shrovetide, after the evening meal, he flew with his friends three hundred and sixty miles from Meissen, through the air, to Salzburg in Austria, into the cellar of the bishop, and they enjoyed the wine there. Then the butler happened to come in and discover them. They were afraid of being caught, and went off in the same way they had come; but they took the butler with them, and in the middle of a forest Faust put him on a very high fir tree, and flew away with his companions.

The fourth anecdote is a trick that does not happen in reality, but only in appearance; still it is at the same time very disagreeable to him upon whom it is played. Faust, as some times before, is sitting in an inn with some friends, and the boy-servant several times fills Faust's can too full. Faust threatens to eat him if he does so again, and, as he does not obey, opens his mouth and swallows him. Afterwards he takes a tub of water and drinks

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\* Chapter 15.

† Zimmernsche Chronik, 2nd ed., vol. I., p. 468/69, 1455.

‡ Chapter 15.

§ Chapter 16.

it out, with the words: "A good drink to a good bite." All the people present are frightened, and the innkeeper threatens Faust should he not return his servant. Faust tells him in reply to be quite untroubled, and to look behind the stove. There the boy lies all wet and shivering. \*

These stories were all that a single man in 1585 could collect about Faust without troubling himself, and without being especially interested in the subject. Mostly they are nice anecdotes, well related by Lercheimer; they have also a certain common centre, but no special impressiveness. Still they are in no way connected with the feelings, the tendencies, or the mental questions of the time. Lercheimer has given no more than a collection of Faust anecdotes.

But only two years more passed before a man appeared who did more than that; who collected the Faust anecdotes, which, until then, went from mouth to mouth into a whole, who brought them under one great point of view, and, by so doing, gave a soul to the Faust legend, and even created it. His name is not known by us, and though he is not a great intellectual hero, certainly the credit belongs to him of having created the Faust problem, and thereby the Faust subject, treated afterwards by many poets. He is the composer of the earliest German popular book on Faust, which appeared in 1587 at Frankfurt on the Main.

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\* Chapter 7.

XI.—*On Telephone Switch-boards, being principally a Description of the New Telephone Exchange, Glasgow.* By WILLIAM AITKEN, Assoc. Inst. E.E., Engineer, National Telephone Company.

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[Read before the Society, 27th April, 1892.]

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(PLATE IV.)

THE telephone between two fixed points, as in a private wire, is speedy enough, and can be made good enough to satisfy the most unreasonable person; but when, as in an exchange system, we wish to connect one wire to any other wire, from No. 1 to, say, No. 5,000, the service must necessarily be slower, and the problem is—What is the least possible time in which this can be done, with all the complicated apparatus of a large exchange, and still maintain the speaking at the maximum pitch?

We can easily imagine a telephone exchange system originating from a very simple start. A business firm, who have had a telegraph line between their office and works, decide to replace the telegraph instruments by the more convenient telephone. This is done, and now all persons desiring to communicate can do so without the interposition of an expert; consequently, business is much facilitated. Communication with a firm a little way off is desired. At first sight it looks as if wires to both the office and works of the first firm would be necessary, as communication is desired with both, and it would be giving the office too much work to ask them to re-transmit all the messages to the works. Some bright genius here suggests that the two wires might be joined temporarily together by a clerk at the office, and such an arrangement is made whereby they are joined together for a few minutes at a time. This is the beginning of an Exchange System—a very rudimentary one, indeed; but a felt want has been created, and experts work out the various details. A small installation such as described could not be worked except under license from the Postmaster-General. It having been decided by the highest legal authorities that the

telephone is a telegraph instrument, he has prohibited telephones between different firms except under license, and then royalty has to be paid to the Post Office. The telephone company have to pay 10 per cent. on their gross revenue as royalty. Only *bona-fide* connections between two branches of the same firm are allowed free.

There are certain features that must appear in all switch-boards, whether they be for two lines or 2,000 lines. *First*—There must be a ready method of indicating to the switch-room attendant that he is wanted to speak. This has been usually done by placing a battery or magneto-generator alongside the telephone in a subscriber's office, and at the exchange end of the line a bell or other indicator. *Second*—There must be a ready means of joining the operator's telephone to the subscriber's line, so that the operator may learn what is desired. *Third*—A ready means is needed whereby the operator can call the attention of any subscriber in the switch-room. A key is generally depressed, joining the line to the generator, and the generator driven, while a bell indicates in the subscriber's office. *Fourth*—There must be a ready means of joining together two wires representing the calling subscriber and the subscribers desired. *Fifth*—A ready means is also wanted of knowing when the subscribers are finished talking, so that lines may be left free for further use. This was usually done by leaving both the line indicators in the circuit when connected, or cutting them out and inserting another in the connecting set.

In boards of 50 to 100 subscribers in the old make, and up to 400 of the new make, these are all the important points that have to be attended to. After the latter number is exceeded, other complications set in, and then, in addition to the foregoing, it is necessary to make provision for joining together a subscriber on A board to a subscriber on B, C, D, or E boards, which might be situated widely apart. In the older form of boards, as the "Williams," this was done by running five wires between A and B boards, five between A and C, A and D, and so on, five wires from one board to every other board in the room. By this method one operator had not full control over a connection, as she had to call or send a message to another board, and ask the operator there to connect a given subscriber on to a given junction wire.

This method was slow, and mistakes were liable to creep in, but a decided advance was made when the Western Electric Company

of Chicago, introduced their multiple boards. Before describing these boards, I wish to call your attention to other three systems, the first two of which have an important bearing on the latter part of my paper. The "Law" system was well known in Glasgow, to a limited extent, some eight or nine years ago, and was well liked while it remained in good order. The telephone instrument had a switch, which, when turned to the left, allowed the subscriber to talk to the exchange operator (who was always listening), and when turned to the right he talked to the subscriber on a direct wire. The chief fault was that, if any subscriber left his switch in a wrong position, several subscribers were cut off. A wire, common to about 50 subscribers, was run in and out of each office; starting from one side of the operator's telephone, it returned to the other after going through all the offices. This wire was used only for giving instructions to the exchange attendant, the subscriber giving his own number and the number desired, as 679 to 770, and when the conversation was finished, he called off as, "679 off." His connections were put on a direct wire running to the switch-room.

A modification of this system, known in Scotland as the "Mann" system, is still used in Dundee and Aberdeen, and a few small towns. The method of working, so far as the subscriber is concerned, is much the same as that already described, with the exception that, after giving the exchange attendant the number desired, he rings his bell, which calls up the subscriber wanted, thus saving the attendant a certain amount of work, and giving the subscriber very little extra. An important difference in the outside work in this system is that, instead of the call wire being looped into an office, a branch wire is taken off, and led to a switch, and the subscriber, by pressing this switch, joins his instrument on to the call wire in a temporary manner, the normal position of the switch keeping his instrument on to his direct line, which is free or disconnected in the exchange. A system such as this simplifies the apparatus in the switch-room very much, and gives the subscriber a speedier and more efficient service. If we examine the connections of the two systems, the "Indicator" and the "Call-wire" systems, we find, in the former, that the subscriber turns the crank and waits till the attendant replies; before she can reply, she has to insert a plug and raise a switch, and sometimes also press a key. With the call wire, the subscriber presses a key on his instrument and the operator is

got, as she is always listening. The number desired is given to the operator, and she tests to find out whether the line is free or engaged (as will be described later); and, if "free," the plug is inserted; if "engaged," the subscriber is told so. If the plug is inserted, the operator has to ring up the subscriber by pressing a key, and speaking to make sure that the subscriber has answered, by the indicator system. With the call-wire system, the subscriber turns his crank, thereby ringing the wanted subscriber. A rule with the indicator system is that no subscriber shall ring except to call the attention of the exchange, but this rule is constantly broken by subscribers ringing to "hurry up" the other party, who probably has left the telephone for an answer to some question; but the result is only to confuse the operator, as her orders are to withdraw the plugs when the subscriber rings on the line, as two rings is the signal to disconnect. But woe betide that operator who then disconnects. The ringing on the line was an indication of impatience and a losing of temper on the part of the subscriber, and the unhappy operator who has obeyed her instructions has to bear the brunt for disconnecting before the conversation was finished. And again, an operator sees the indicator drop of a subscriber who is guilty of ringing on the line; she thinks he is at his old tricks, and, remembering what she got last time, she leaves him alone to ring through. It so happens that he wishes a second connection this time, and the complaint now is—Why did you not disconnect me when I rang off? Unless the rule referred to is strictly enforced, there must be confusion, and our Glasgow subscribers have broken the rule so ruthlessly, and so desire to break it, that it has been thought better to depart from the "indicator" system and adopt the "call-wire" system, where ringing does not indicate in the exchange, but calls only the distant subscriber, and when disconnection is wanted, the key is depressed, and the exchange told, "679 off."

The Post Office is the only exchange with which they have been successful—namely, the Newcastle one, which has some 500 to 600 subscribers—the work is done in rather a novel way, but one, I think, that is not capable of development for large exchanges. The distinctive feature of it is that there is always a permanent current on the line of some 20 milliamperes, which holds up the shutter of the electro-magnet and deflects a needle. When a subscriber lifts off the tubes of the Gower-bell instrument, the

battery which is at the subscriber's office is cut off, and the shutter drops. The attendant answers, and joins the line to the subscriber wanted by a length of double cord, with plug at each end. The two conductors in the cord are crossed—that is to say, each is joined to the top part of the plug at one end and the bottom part at the other, so that, when the conversation is finished and the tubes are hung on the levers, the permanent current goes to line and deflects the needle of the indicator. If the two conductors were joined straight through, the two currents would oppose, and the needle would not deflect. At first sight this looks a beautiful system, but the trouble with batteries is serious, requiring almost constant attention. A subscriber may only use his telephone five minutes in a day, yet this—in many cases, huge—battery has to be constantly kept in circuit. They are paying very dearly for the good points which this system possesses. This system is worked with the almost obsolete junctions between the various boards, though there is word of them now putting in boards more nearly up to date.

When the Western Electric Company, of Chicago, introduced their multiple boards some five or six years ago, an immense stride was made in the history of telephonic development. Before they came to hand, all exchanges were worked as before mentioned, with junction wires between boards. These were done away with; instead, they repeated a subscriber's line on every board in the switch-room. A subscriber's wire, on entering the switch-room, goes to a "jack" (or set of springs into which the plug is inserted) on the first board, to the second, third, and so on, to a jack on every board to the last, then returning to the board on which he is to be answered—if No. 1, back to the first board; if 1,000, only back to the fifth board (200 lines being on each board). There it goes through local jack and indicator to earth or to return line; so that while, as on the old boards, the subscriber only rings up at one point and is attended to there, yet his line is within reach of every operator in the room for the purpose of being connected to any subscriber who rings up for him. With such a system it became necessary for the operator at one board to know whether or not a subscriber was engaged at another, and this is attained by running an extra wire for each subscriber's line throughout the length of the boards. Starting from the first jack "free," it is attached to the body of each jack, and finished "free" at the last.

Most telephone renters think that after their line is run and

connected, the telephone company have nothing further to do than touch up their instruments occasionally, while really the company, for every 200 new subscribers added to their central switch-room, have to bring the 2,500 old subscribers alongside these 200 by putting in 2,500 extra jacks, and 75,000 feet of new wire in cables. Then these 200 new subscribers must each have a jack placed on each of the fifteen old boards of the room, which means other 3,000 jacks, and 60,000 feet of wire in cables. In a conversation which I had the other day with a New York electrician, when he heard that our rate was only £10, I was asked if we meant to retain that figure with our large exchange. On being informed that such was the intention of the company, and that the people here were crying out for cheaper telephones still, he remarked that they in New York could not do it, owing to the extra apparatus and extra wire required for the old subscribers' lines as the exchange grew larger, and they had been forced, in consequence, to increase their rate to £30 per annum. Besides the multipleing of the subscribers and the engaged test, which were the outstanding feature of these boards, all the various parts were wonderfully improved and made much more compact. A section of 100 jacks was put into a space of 15 inches by 5 inches, and that size has been still further reduced to  $11\frac{1}{2}$  inches by  $3\frac{1}{8}$  inches. The indicator was remodelled altogether, and the operator's telephone set and method of operating were very much improved. The principle of working remained as previously described, the "engaged" test being additional. Now, when two lines are joined together, say, on A board, the connecting plug joins together the two lines by the cord on the one hand and top spring of the jack on the other, lifting the latter off the bottom contact, thereby cutting off the right-hand section of both exchange connections, including the indicators, but putting in a ring-off indicator instead, and at the same time joining the "click" line to the upper spring by the plug. This free line, being tagged in, does no harm. Suppose now, another subscriber further up the room rings up, desiring to talk to one of those already engaged, the operator lifts one plug of the connecting set in front of her (and which has a battery in circuit), touches the front of the nearest jack of the line asked for, at the same time keeping the receiver to her ear. The battery in the cord now gets earth through the click wire by the subscriber's line, and she hears a click in her telephone, showing that the line is engaged. Had the line been disengaged, her

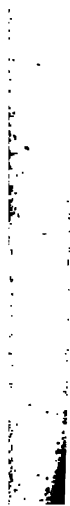
telephone would have been silent, as the click wire in itself is an insulated wire.

The newest board of the Western Electric Company is their "mixed circuit board" for working single wires and metallic circuit lines together. The working, so far as the subscriber and operator are concerned, is the same as that at present in use. It is being taken up charily in this country, owing to its very complicated nature. The single lines have all artificial resistances in the earth at the exchange. When a single wire is joined through to a metallic one, the latter is "earthed" through a retardation coil. Condensers are joined up in the operator's circuit; and as, when a complete metallic system is introduced, all these complications are useless, and the whole board has to be altered, we, in Glasgow, have decided to have nothing to do with it, but mean, when the day does come for a complete metallic system to be adopted, to make the change general at once. With our new boards, we will be able to work "metallic" where wanted, making a slight alteration at the subscriber's office, instead of complicating the exchange.

This brings me now to a description of our new switch-board. We have been extremely fortunate in getting a very fine hall in the Royal Exchange, which was formerly used as the sugar sample room. It is 95 feet long by 27 feet 6 inches wide by 26 feet high, and will be the finest switch-room in this country. Two rows of switch-boards will run from end to end of the room, a broad passage being left in the centre, and narrower ones between the boards and the side walls. These boards will be capable of working 8,400 subscribers, 400 trunk or long-distance wires, and 400 junctions or wires to suburban and other exchanges in Glasgow other than the central.

All the fittings and wiring will be double or for metallic circuit working, so that, if it is ever thought desirable to introduce such a system into Glasgow, our switch-boards are ready, or if any subscriber who uses the trunk lines very much desired that his local line should also be double, he can have it without any trouble on the company's part, though we will likely put him to the trouble of paying a little extra. A switch will be placed in his office, making his line into a single one for talking locally, and double for talking on trunks. The normal position of his line being as a single wire, the switch will work automatically as regards bringing his line back to that condition after talking to a distance.

The boards will be of a pattern known as duplex—that is to say, the jacks are placed with their faces looking upwards, forming a flat table-like surface instead of an upright face, as with the present boards, so that the jacks are common to two sets of operators, who sit on both sides looking towards each other, and make the connection by a downward movement. A 200-line board now in Paisley, and one of 800 in London, were the first made after that pattern, and a few others have followed; but ours is the first on a very large scale. While in principle they are the same, in detail they are widely different; the two mentioned being on the indicator system, while this is adapted to the call wire. The great advantages of the duplex boards are (1) that in a given space nearly double the number of subscribers can be accommodated as on the upright pattern; (2) the number of jacks required is halved, and the amount of wiring necessary is more than halved. In an exchange of, say, 2,000 lines, the material necessary for No. 1 line on the old pattern would be 10 jacks, one on each 200-line board. Two or three wires, depending on whether double or single circuit is used, running from 1st to 10th jacks, say, 100 feet, and then from 10th jack back to indicator on first board, other 100 feet; total, 200 feet. By the new pattern there would only be five jacks necessary, one on each 400-line board, and 50 feet of wire. The wire terminates at the last jack, so that is the total length of wire. We have still further reduced the size of block containing 100 jacks to  $10\frac{7}{8}$  inches by  $3\frac{1}{4}$  inches, and these are of an entirely new and improved pattern. Instead of the two plugs and cord and ring-off indicator, &c., which we have at present, a branch connection will be brought from the nearest jack to where the subscriber is to be attended to, and taken to an overhead cord and plug. As these new boards are to be worked with single cord, every subscriber's line will be terminated in a plug, so that it will be impossible for a subscriber not to get a connection owing to the connecting plugs being all engaged, which sometimes happens with the present system. Another advantage of the single cord is that only one movement is necessary to make the actual connection; of course, it is first necessary to find out whether or not the subscriber wanted is disengaged. The click wire in this case runs from jack to jack as before, the spring with the click wire making connection with the front part of the jack in the normal position; but when a connection is made, the plug lifts that spring by an insulated stud,



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so that the plug does not touch it, and forces it against the earth bar, thus engaging the line. An operator at another board desiring the wire touches the front of the jack with her test thimble, which has a connection with her telephone and through battery to earth, with the result that her receiver *clicks*, the battery getting earth at the other board.

As mentioned more than once, subscribers have the use of a common wire to the exchange for calling purposes, and the two direct wires when joined together become practically a private wire, where the voice of the operator is not heard saying, in dulcet tones, "Are you finished," before you have commenced to talk. They will be left undisturbed until the subscriber who originated the conversation calls "off." Should he fail to do so, other subscribers desiring conversation with these two firms will be told they are "engaged." You will therefore see how necessary it will be for the subscriber, when finished talking, to tell the operator to disconnect. Should either of the subscribers desire another connection, of course, the mistake would be noticed, but they may have lost business in the interval. As the connection is made on the calling subscriber's board, it is his duty alone to call "off," for the other to do so will only cause confusion, as it would be necessary for the operator to leave her table and examine every board in the room to find out where the connection had been made, so he must trust to the former doing his duty, which, if he fails to do, the innocent must suffer with the guilty.

The call wire is used to all exchanges within three miles of the central just now, and this will be developed still further. An operator has at hand a series of keys, by pressing one or other of which she can get the exchange desired—an operator always listening. Only on trunk wires will indicators be used, and these will be iron-sheathed for high self-induction, and wound to 1,000 ohms. They will be shunted across or bridged-in on all double wires, and shunted to earth on all single wires, so as to have no electro-magnet in the circuit to retard the current. The connecting of single wires to double is, and will still be, made by a repeater, or transformer, the primary and secondary of which are, respectively, of 150 and 290 ohms resistance, and are wound alternately, and the whole sheathed with soft iron wire. Speaking through these is very efficient, and, as they are sheathed with iron, the operators can ring through them, thus saving the necessity of having two sets of ringing and speaking

keys as formerly. Special keys have been designed for cutting in and out the repeaters as required, instead of using two sets of jacks and connecting sets, as is commonly done. The board, with nearly all its fittings, has been designed here and specially made for Glasgow.

In the foregoing I have tried briefly to describe the development of the switch-board, giving you, in the latter part, an indication of how we mean here to try and solve the problem of speedy and sure telephony. We anticipate a great improvement on our present service, good as it is. The subscriber will call the operator *immediately* he goes to the instrument. He will be connected, if the line is disengaged, within 10 seconds. Before you are connected, your bell will not ring when the crank is turned, but immediately the two lines are joined your bell operates as well as that in the office wanted. If the number asked for does not reply readily, it must be the fault of that subscriber, as he is being rung direct by yourself. Ring as furiously as you like, you have the satisfaction of knowing you are making his bell resound; and the operator is at peace, no complaint next morning from the subscriber saying, "John Jones & Co. write me saying they tried to get me between 2 and 3 o'clock yesterday, but failed; we were never away from the telephone all day," forgetting that he made a call at that hour, and the clerk, who should have been in, was in the next office having a talk with a friend. And you will be no more called up a second time because of the exchange failing to disconnect. If you are again rung up, it is your own or your neighbour's fault. A second connection can be got immediately by pressing your key, and saying, "No. 2679 off, and on to 1427." We are asking you to ring up your own connections, but I do not think this will be objected to. I always think subscribers like to ring, they think they thereby hurry the operator, whereas they keep the connection back by dropping the indicator after it has been replaced, and ringing in her ear when she wishes to tap or listen on another line to help things forward. Instead of ringing the exchange, you will now really hurry up your neighbour.

With the advent of our new boards, which will not, however, be ready till October, we trust a time of peace and contentment and satisfaction with the service will come to all our subscribers.

EXPLANATION-OF PLATE IV.

Fig I. (a)—Connections of Subscriber's direct line in Exchange, showing it multiplied through three boards.

(b) Subscriber's call-wire, connecting to junction call-wire switch and operator's telephone set in Exchange.

Fig II.—Connections of Trunk Line, showing it multiplied on two boards, and the method of operating it in Exchange.

Fig III.—Diagram of Western Electric Company's single-wire board, at present in use in Glasgow. (a) Connections of Subscriber's Line, showing it multiplied on three boards. (b) Cords and Plugs for connecting Subscriber's Lines together.

Figs IV.—Diagram of call-wire system.

XII.—*Warming and Ventilation of Public Buildings with or without Motive Power.* By J. D. SUTCLIFFE, Manchester.

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[Read before the Architectural Section, 18th January, 1892.]

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(PLATES V. AND VI.)

FOR eight years I have devoted myself entirely to the subject of Mechanical Ventilation, and I have, during that period, inspected and reported upon upwards of four thousand buildings. I have been gaining a little experience every day, and I wish to draw a few forcible conclusions from my experience. I may not give you a scientific lecture, but I will keep my own theories out of it, and give you, as far as I can, practical demonstrations founded on experience only. I went out last year to the United States specially to see and examine the Smead system of warming and ventilation, and after visiting about fifty schools and other public buildings, I came to the conclusion that we have nothing on this side of the water to compare with it for efficiency and completeness, and, in general, that Smead's work was twenty years ahead of us.

After these few words of introduction, I purpose briefly glancing at the history of mechanical ventilation, and although I place Scotland in the front rank, as far as the British Isles go, yet, twenty years before mechanical ventilation was thought of in Scotland, it had become recognised in America as the only safe plan on which large buildings could be ventilated. Mr. Kirkbridge, who wrote in 1880, said that there seemed to be little difference of opinion amongst those who had charge of American hospitals in reference to the proper method of warming and ventilating these institutions, the Association of Medical Superintendents having so long ago as 1851 unanimously resolved that all hospitals should be warmed by passing an abundance of pure fresh air from the external atmosphere over a radiating surface. They also agreed, with equal unanimity, that a complete system of forced ventilation in connection with the heating was indispensable to give purity to the air, and that no expense which was required to obtain that object could be deemed misplaced or injudicious. These provisions were adopted in 1851, and as no change, so far, has been suggested in them, after forty years of extensive experience by highly intelligent men in various climates, it is quite safe to say that this declaration is unquestionably true to-day.

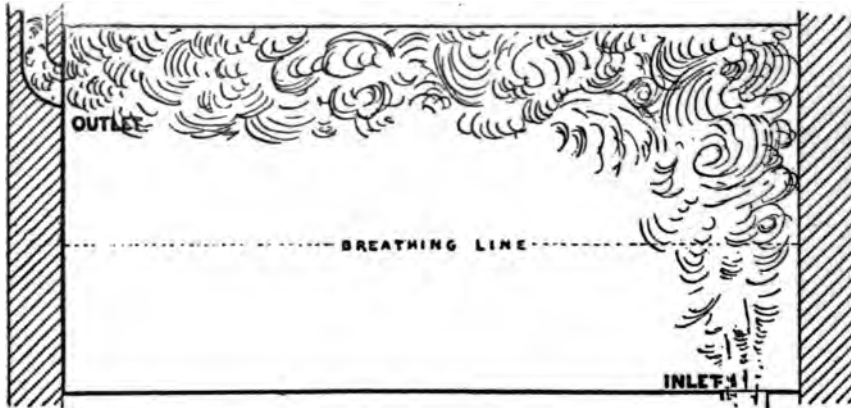
Glancing further at what you have done in Scotland, I believe that Mr. William Cunningham, of Dundee, was the first to employ a mechanical system of positive ventilation to school-rooms in this country on anything like common-sense lines. I lately had the pleasure of inspecting his first mechanically-ventilated school, which is a factory school in Dundee, and I have made a plan and section, which I show here for your information. Mr. Cunningham is a skilled engineer, but unfortunately, from a ventilating point of view, he is also a flax-spinner, and this means that he can only give his spare time to the work of ventilation. I believe if he had been able to devote his whole time to the work, he would soon have found out the weak places in his system, which I shall shortly endeavour to explain.

You will note how the air is admitted at each end of the school-room, and how it is drawn off on each side. With such an arrangement, it is quite impossible to have an even diffusion of the warm air. I wish to call your attention to the six illustrations showing how warm air really behaves in a room. The illustrations are by Mr. Briggs, of Bridgeport, an architect who has achieved an enviable reputation as having greatly assisted in the development of economical and sanitary warming and ventilation for school buildings. The circumstances attending the tests, illustrations of which I present here, entitle them to more than usual consideration. These experiments were made by a party of gentlemen who were honestly endeavouring to learn the method of introducing and exhausting which would most thoroughly utilise the warmth and freshness of a current of air passing through a room. They were not interested in any heating and ventilating scheme or apparatus. None of them had any special theory or hobby, and, unlike most diagrams of this kind that have been presented to the public, they are not what were supposed to be the courses of air currents to carry out someone's theory, but the particulars of what was actually visible to the party as they were looking through the glass partition. It must be borne in mind that the air in this room was protected from all the disturbing elements, and, unlike an occupied room, the current inside was not affected by the breathing or the moving of the occupants; or, in other words, it was in the condition of an empty school-room.

In Fig. 1 you will note that the warm air is admitted at the floor, and extracted near the ceiling. This is on the principle

that many people seem to believe in—namely, that warm air must be bad air; and it is this that has caused many rooms to be ventilated, as they call it, at the top. It is also a popular mistake to believe that the breath rises to the ceiling, leading to openings being generally made at the top; but as they

FIG. 1.



let the warm air out and leave the occupied portion cold and foul, they are always closed in winter, and consequently the ventilation is *nil*, or it is bad.

In Fig. 2 there is shown the air admitted about eight feet high on one side, and taken out near the ceiling on the other side, leaving the whole of the space below eight feet necessarily without any warm pure air.

FIG. 2.

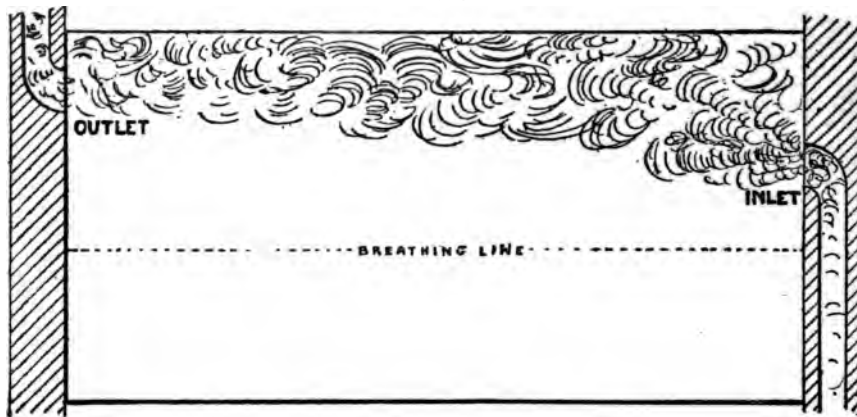
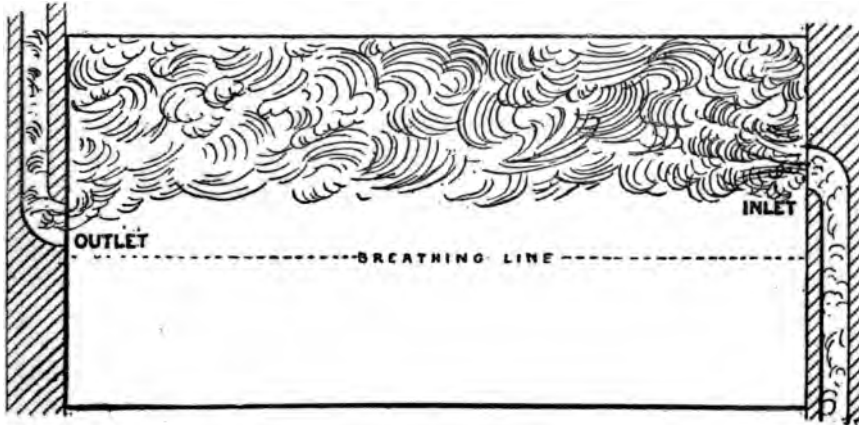


Fig. 3 shows an approach a little nearer to the right method, as the outlet is brought rather lower down.

FIG. 3.



In Fig. 4 the arrangement is still better, the outlet being brought to the floor, the inlet being still kept about eight feet high.

FIG. 4.

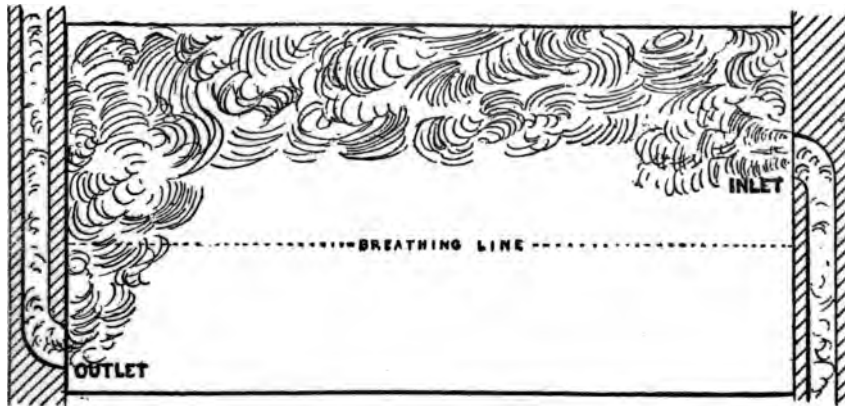
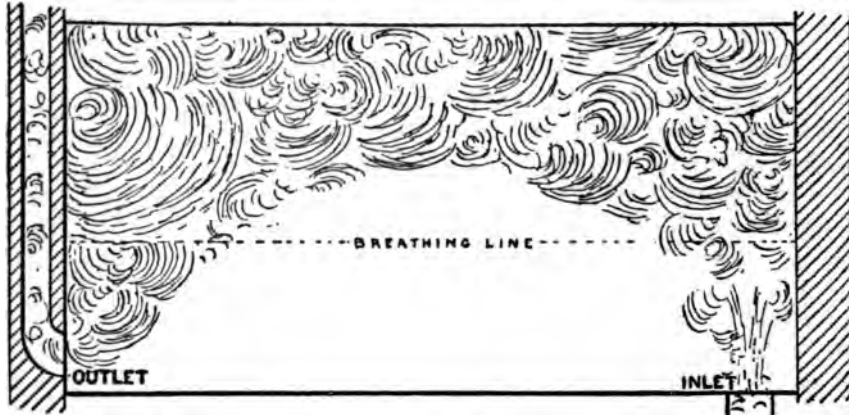


Fig. 5 gives a plan which comes very much nearer the perfect system, as the inlet is at the floor, and the outlet is also at the floor, leaving but a very small space unaffected. Mr. Smead speaks of going to examine a church where this method of admitting and exhausting the air was adopted. He says:—"I went to the building with the pastor and a number of the building committee. The

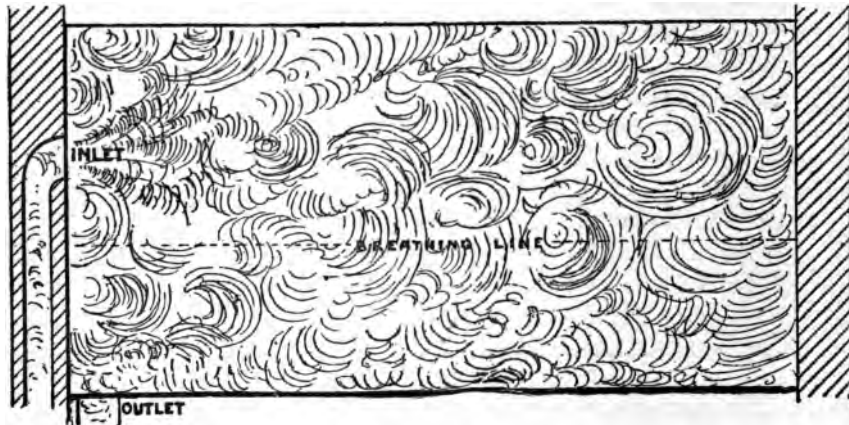
pastor said he could not understand why the people complained, as they had four large furnaces, and it always seemed warm

FIG. 5.



enough in the pulpit. The committee remarked that they could not all occupy the pulpit, and it was cold down in the pews." This illustration (Fig. 5) explains very clearly why that was so.

FIG. 6.



In Fig. 6 is shown a perfect distribution—at once the most natural and most effective.

Now you will understand what I mean by the weak places in Mr. Cunningham's system. Unfortunately, almost all the

subsequent work done in schools has been done on Mr. Cunningham's lines, little original thought being brought to bear on the subject; and, so far as I know, the last buildings which are mechanically ventilated copy the faults as well as the virtues of this first school of Cunningham's.

There is, however, one notable exception, and that is in the form of blower used. Mr. Cunningham used an air-pump, and one of the same is in use to-day, but it is cumbersome and expensive, and I doubt very much if another will ever be made. When Mr. Cunningham read a paper before the School Board of Aberdeen in 1884, he said what he could in favour of his air-pump, and against the use of ordinary fans. But he was strictly fair, and he remarked—"If it is thought that I am too particular, and that something of a much simpler and cheaper form of machine, such as the Blackman Air Propeller, will serve the purpose equally well, let it by all means be tried. I have designed machines because they were thought to be necessary. If we can get the same result in a simpler way, you will find me not only frank enough to admit it, but pleased to know that mechanical ventilation has been simplified." These were generous remarks, and a Blackman fan was tried in one of the first schools which he ventilated in Aberdeen. Since then, thousands of successful applications have been made in accordance with plans and instructions furnished by the Blackman Company, who thankfully acknowledge the valuable co-operation of many men of Mr. Cunningham's stamp who have so fully appreciated the advantages to be gained by moving air in large volume, but at minimum speed and pressure. The constant effort of the Company to secure, as far as possible, the success of every "Blackman" sent out, has had the natural result; and now, in every trade throughout the world, the Blackman fan is doing good work, over 10,000, averaging 36 inches diameter, being used for industrial purposes alone, displacing hourly over six thousand million cubic feet of fresh air. The conditions of the *workers* are immensely improved, and Parliament should now turn its attention to the needs of the *school-children*.

I wish now to explain to you, as well as I can, in detail, the Smead system, which is a warm-air system, as distinguished from a steam-heating or hot-water system. I have never seen a hot-air apparatus working satisfactorily in this country, and the chief reason for the failure was that the furnaces were not of sufficient

capacity, and no proper system of changing the air was adopted, the result being that the air was scorched. Mr. Smead gives the following reasons why this system is to be preferred, and from actual experience I confess that all he claims he makes good :—

- 1st. Because the first cost of the “Smead” is about one-third less than for first-class steam heating.
- 2nd. Expense of fuel is from one-third to three-fifths less.
- 3rd. There is no possible danger from explosion with air warmers, whilst with steam there is constant danger, whether the pressure be high or low.
- 4th. There are no water pipes to freeze or burst and let water through the building, ruining plaster and furniture.
- 5th. Repairs for steam boilers, pipes, and pumps will cost in the first ten years ten times as much as for the “Smead,” and the repairs must always be made by a steam-fitter, or other skilled mechanic, while any caretaker can repair a worn-out air warmer.
- 6th. The “Smead” will warm the air in any weather, no matter how low the outside temperature may be.
- 7th. With it, the building can be warmed in one hour from the time the fires are fairly burning; while with steam four or five hours are required, and I have known twelve hours necessary.
- 8th. Three-fourths of the force generated by the burning fuel in steam apparatus is lost in the form of mechanical motion, and does not appear as temperature in the room; while in the “Smead,” seven-eighths appear in the room as temperature, and only one-eighth as loss.
- 9th. With the “Smead,” absolute uniformity is secured throughout the building; while with steam-heating apparatus, the rooms furthest away from the boiler are 10° to 15° colder than the nearest rooms in extremely cold and windy weather.
- 10th. The warming is easily, and in fact necessarily, combined with the ventilation.

These are some of Mr. Smead's reasons for preferring warm-air apparatus to steam or hot-water heating.

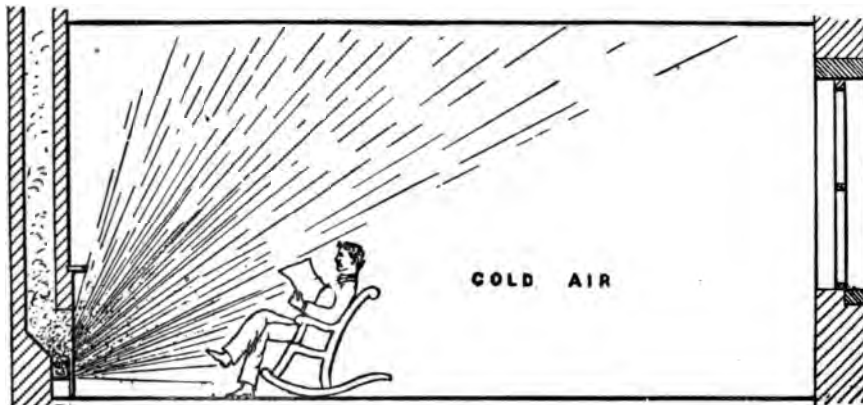
Heat may manifest itself in two ways—namely, as temperature and as expansion. All the force generated by the burning fuel will appear in one of these forms or a part of both. Water at the normal pressure can be heated only to  $212^{\circ}$ . Consume as much fuel as you will, and the water will still remain at  $212^{\circ}$ . The energy generated by the consuming fuel is not lost, but is transmitted to the water in the form of expansion, and the water is converted into steam. Now, if the water be confined, and this tendency to expansion resisted, the temperature can be raised to almost any extent; but if not thus resisted, the temperature will not rise above  $212^{\circ}$ . As it is necessary to force the steam through the pipes, this expansion must be resisted until sufficient force is accumulated to accomplish this result. This mechanical work is performed at the expense of fuel. If a building is warmed by steam, three-fifths of the force generated by the burning fuel will be consumed in the form of mechanical motion. The temperature of the steam in the boiler may be  $400^{\circ}$  or  $500^{\circ}$  F. On the other hand, air may be heated to  $600^{\circ}$  F., so that nearly all the energy developed by the burning fuel appears as temperature, while scarcely any of it appears as mechanical motion. Here we see why Ericson failed in his attempt to use heated air instead of steam as a motive power. Heat being applied to the air appears as temperature, but being applied to water appears as expansion or mechanical motion.

Few persons seem to understand exactly how the air in a room is warmed. It is generally thought that the air in immediate contact with the burning fuel or heated stove is warmed, and that this air warms more air, and so on until all the air in the room is heated. This is not so. In the case of an open fire, the air next to the burning fuel is warmed, and for the most part goes up the chimney. A small part, however, rises in the room, and the cold air takes its place.

In Fig. 7 is given a representation of a room warmed by radiant heat from an open fire. You will note that the man reading has already raised one foot out of the cold, and, as Mr. Smead says, by and by he will want to turn round and warm his back. The open fire place is certainly "sociable" and serves well if the room is supplied with a large volume of fresh warm air from a register, otherwise the fire place will draw cold air into the room through every crevice and opening. This cold air falls to the floor, diffuses along it towards the fire, and the occupants suffer from cold feet;

so that only a small part of the air in a room is warmed, as the heat is mostly spent on that which escapes up the chimney.

FIG. 7.



I am here to plead for fresh air for the children. When Parliament passed an Act last year compelling all cotton manufacturers who use artificial means of moistening the air in their sheds to supply at least 600 cubic feet of fresh air for every person employed, the employers cried out loudly that their trade would be ruined. Instead of this, they have now to confess that their weavers are getting better "averages" from their looms, and consequently masters and workers are getting more money. But what would our manufacturers have thought if they had to supply, not 600 feet for each person, but 1,800 feet, as in the State of Massachusetts?—and this applies not only to factories, but also to schools. I would like you to recognise what this means, and I hope the time is not far distant when the Government, or some Member of Parliament, will have courage enough to bring in a bill to do the same here. No one denies the value of good ventilation, and popular interest is now aroused to a certain extent. I know from experience that to educate the public concerning the right principles of ventilation is a laborious and costly task. The care of health and life may be said to be an individual concern; but if habits and customs are shown to be perilous to the public health, it is not deemed an invasion of private rights to invoke the strong arm of the law. Authentic records tell us that one-third of the children born into the world

die before they reach the age of five years. The practical question of the day is—What can be done? We must begin with the children in the schools.

The constant crowding of children in school-rooms not specially adapted to secure change of air is injurious. The air is loaded with noxious exhalations from the lungs and skin, and these chiefly condense on walls and windows. In such rooms the lower current of air is cold, and the higher is superheated. The children suffer from cold feet and burning, aching heads. Professor Draper, in a lecture delivered to teachers, some time ago, said:—“The ordinary condition of the unrenewed air of school-rooms is quite enough to astonish us, if we stop a moment to think of it; for there are not only the inevitable vitiating effects produced by respiration and the constant activity of the skin in persons who are healthy and cleanly, but the additional exhalations proceeding from unclean bodies and ill-ordered mouths, from decaying teeth and dirty clothing, which too frequently accompany the city school boy and girl to the crowded room which is the scene of their daily tasks. Many children yield easily to contagious disease through the enervating effects of breathing an unwholesome school air.” If the physical condition of school children is not what it ought to be, our education is maintained for inadequate results.

I have made large diagrams, showing plans and sections of two buildings—the one warmed and ventilated on the Aspiration method, and in its details known as the Smead system; and the other, a mechanical method, known as the Blackman-Smead system. After making a few general remarks on both systems, I will go into details.

By the Aspiration method I mean heated chimneys or shafts for the removal of foul air. Heated air expands, and the expansion is equal to  $\frac{1}{480}$ th of its volume for each degree Fahrenheit that the temperature is raised from 32° to 212°.

Mechanical ventilation is produced by the action of fans creating an air movement, regular and unvaried, in stated volumes, removing the foul air as fast as it is vitiated and drawing in fresh, pure air, to take its place.

The Smead plans (Plate V., Fig. 1\*) before you show a school at Pawtucket, Massachusetts. I examined this school very carefully, and I believe it to be one of the finest schools

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\* Section only shown in this reprint.

in America. You will see that much more is made of the basement in America than we make of it in this country. Four air warmers are employed, and two large ventilating stacks. I should like you to follow with me the progress of the air, where it enters the fresh-air rooms, passing afterwards under and over the four heaters, and then finds its way through the vertical air ducts to the various rooms above. Another thing that will strike you in this plan is, that the closets, eighteen in number, are in the play-rooms. If we had to suggest anything of that kind here, I am sure that it would not be listened to; yet I say that there was less smell from those eighteen closets and from a large urinal than there would be from a single water-closet of the best construction. You will note in the section how the warm air rises through the flues and is distributed through the rooms, returning to the foul-air chamber on the same side of the room as it left the warm-air register. It is then brought down into the foul-air duct, which you see distinctly marked in the basement, and from this duct it is carried underneath the closets. The action of this warm air is to evaporate all the moisture in the excreta, and the air is then drawn forward by the ventilating shaft (which, by the way, has a large heater fixed in it to rarify the air and induce a strong current), and so the foul air is carried above the top of the building. The draught in these closets is so strong that when I lifted the lid and stood nearly at my full height, the smoke from a cigar was drawn down through the seat-hole into the closet, and none of it escaped into the room. I saw in some of these schools samples of deposits that had been in the school all the school year, namely, for ten months, and from these there was not the slightest odour, and you could handle the dried excreta in much the same way as you could handle dried chips. At the beginning of the long summer vacation, it is a custom to pour a small quantity of kerosene upon the stalagmites of dried excreta, and set fire to them. The whole of it is consumed, and passes away up the chimney, nothing being left but a little dry ash which can be swept out.

The ground floor plan calls for very little remark, excepting as showing how it differs from that of our schools. You will note that there is no large assembly room, and that the four rooms on this floor are each adapted for forty-four pupils, giving a floor space to each pupil of 20 square feet, and a cubic space of 250 feet. The class rooms, you will notice, are very carefully

warmed, and there is also a large warm-air register in the floor in each corridor. This register is always open, so that if the teacher closes off all the warm air from the school-rooms, there is still an exit for it into the corridors.

In the first-floor plan there are again shown four school-rooms, two of them for forty-four pupils (as on the ground floor), one for sixty-five, and the other for seventeen pupils. The room for sixty-five pupils is, I think, the largest room I have seen in America, most of the school-rooms being built for forty to sixty pupils. It is interesting to note that even this large room is warmed from one air register grid, the outlet of which is 36 inches by 20 inches, and there are two foul-air outlets on the same side of the room measuring 34 inches by 32 inches. The section I have here shows you clearly how the air is passed from the fresh-air chambers to the various warm-air flues. You will note special arrangements of "Smead" for admitting all-warm air or all-cold air, but the teacher must have the full quantity coming into the room, warm or cold, so that it is quite impossible to stop the ventilation. There are no valves to the outlet ducts; these are always open. If the teacher wants the air cold, he has only to raise the valve, and then the fresh air passes under the heater, and gives very little warmth; but if he requires the air to be warm, he lowers the valve, and allows the air to pass through and over the air warmer to the top of the chamber. It then passes forward directly to the school-room as warm as necessary, and if any intermediate warmth is wanted, some of the air can be passed under the heater and some of it over, and the air will be thoroughly mixed before it enters the room. In this section I want you also to notice the heater for the ventilating stack; it is fixed just above the opening from the closet vault, and this ventilating shaft is about 4 feet square. These plans give a good idea of the Smead system, of which the Blackman Ventilating Company, Limited, are the sole licensees for Europe.

I wish now to show and explain to you the Blackman-Smead system of ventilating and warming, which differs from the "Smead" in the important point that it is mechanical, as against a system of aspiration. You may ask—If the Smead system has been so successful in America, why should you wish to alter it? The reasons are few and simple. In America the atmosphere is, as a rule, clean and clear. The buildings need not be very near to other buildings, and there is no difficulty in

getting a good air supply. The basements are excavated throughout, and there is plenty of space to get the air warmers adjacent to the warm-air flues, and directly under the rooms to be warmed. Where these conditions can be had here, as in some of the country schools, nothing but the Smead system is necessary.

Unfortunately, in all our large cities and towns we cannot get a supply of clean, fresh air, and so we must filter the air as it enters our fresh-air room. The filters to keep out soot and dirt offer such an obstruction to the air that nothing less than motive power will drag it through them. The Blackman fan, from the shape of its blades, is enabled to do this to perfection. The four illustrations, numbered 2, 3, 4, and 5 (Plates V. and VI.), show in plan, elevation, and detail the application of the Blackman-Smead system of warming and ventilating to a building by the single-duct system.

Fig. 2 gives the plan of the basement, showing gas engine, tubular air warmer, Blackman fan, wet screen, and air ducts. The "Blackman" pulls air from outside into the fresh-air room, thence through the wet screen, which will intercept the soot or dust that may be in the air. The cold air then passes to the tubular air warmer, which raises its temperature to 100° or 120° F., and thence into the mixing chamber, into which cold, fresh air can be admitted by the door, so as to produce such a degree of temperature as may be desired. The "Blackman" forces this air through the horizontal duct to the vertical flues that lead to the rooms above.

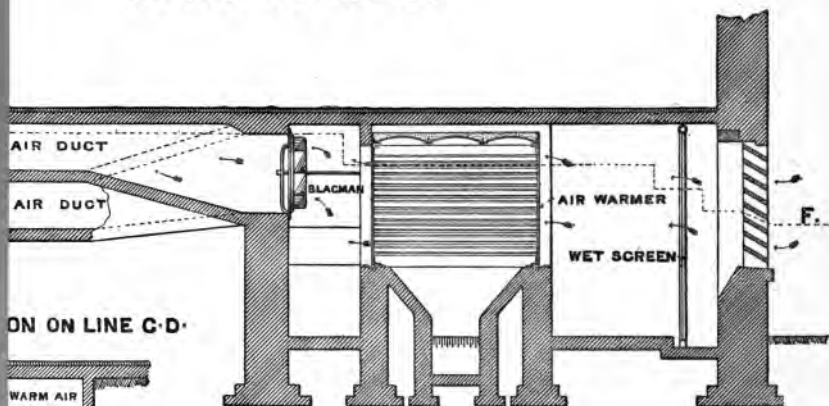
By this means the building can always be flooded with pure, warm air in winter, and pure, cold air in summer; and as each room has its own separate flues, any room can be supplied with warm air in winter and cold air in summer, independent of the rest.

In Fig. 3 is given the plan of the ground floor with the warm air and ventilating flues. The corridors also receive their supply of fresh air from independent flues, and are therefore kept warm and sweet, which is not often the case in public buildings. The ventilating flues run up to the roof space (as shown in Fig. 4), where horizontal ducts lead the vitiated air to the tower, from which it escapes into the open air.

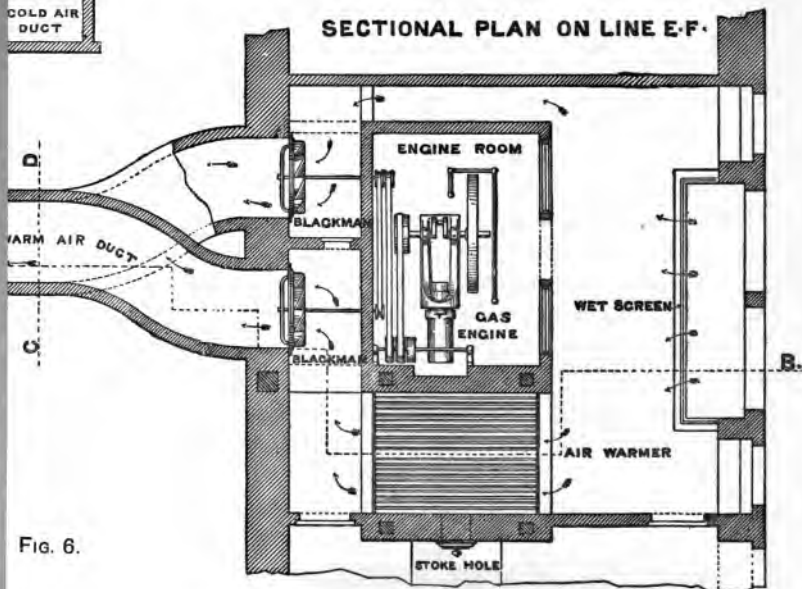
Fig. 5 shows a section through the building, indicating the air warmer, the "Blackman," the horizontal ducts, and the vertical flues, with the inlets about 7 feet above the floor of the room.

**BLACKMAN-SMEAD SYSTEM  
OF WARMING AND VENTILATING  
SHOWING PLAN AND SECTIONS  
OF THE DOUBLE DUCT METHOD**

**SECTION ON LINE A-B.**

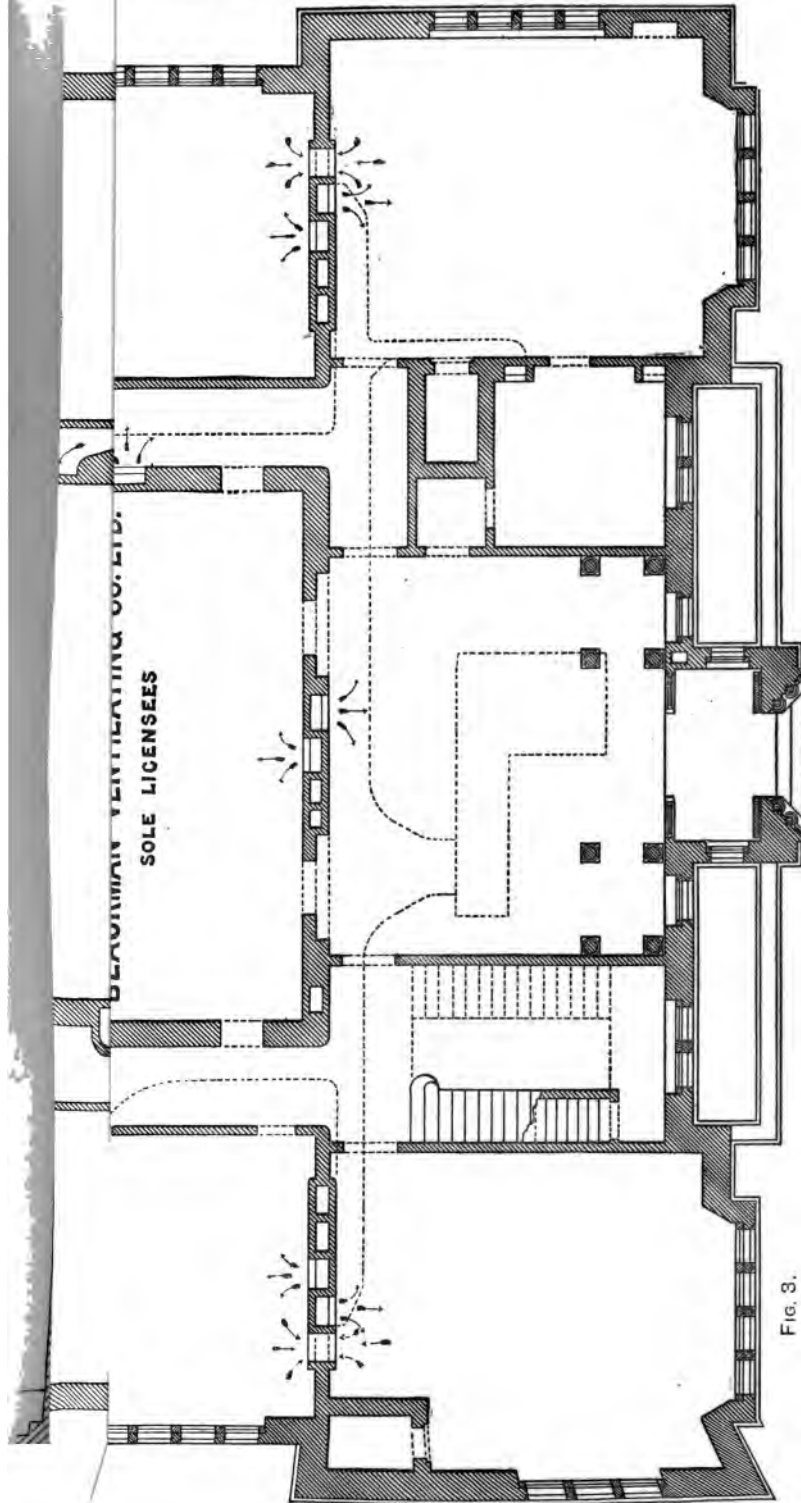


**SECTIONAL PLAN ON LINE E-F.**



**Fig. 6.**







Fan registers are placed over the inlet and the flow of air is controlled by them. The exhaust registers are placed near the floor line, by which means the vitiated air is drawn off through the ventilating ducts to the tower. In places which are liable to winter fogs, and where, consequently, a large amount of gas is consumed for lighting, a register can be placed near the ceiling line to carry off the gas fumes more quickly.

In Fig. 6 are given a basement plan and a section of a building, showing the Blackman-Smead system of warming and ventilating by the double-duct system, in which one horizontal duct is placed above another. At the entrance to each duct a "Blackman" is placed, which forces cold air into the lower duct, and warmer air into the upper one. From the sides of these horizontal ducts, flues are carried up to each room in the building. At the bottom of each flue is an opening into the cold air duct, by which cold air can enter the flue; above this is another opening, which admits warm air to the flue. Between the two openings, a valve is hung in a frame, and this valve is controlled by a chain from the room above. When the valve is down, warm air only is allowed to pass up the flue into the room. If the room becomes too warm, the valve can be raised, so as to allow cold air to enter the flue and mix with the warmer air, thus reducing the temperature of the admitted air, but without restricting its volume. By this means, continuous ventilation is assured at whatever temperature may be desired, regardless of the pre-occupation of the attendant. In many buildings it is desirable, and often necessary, that different rooms should have different temperatures. When this double-duct method is used the temperature of each room is under the control of the occupant.

Sometimes we employ a continuous warm-air flue running up through the different storeys of a large building. The air is pulled through a wet screen, warmed by a tubular air warmer, and forced up the flue by the "Blackman." The swing valve catches the current and diverts it into the rooms on the several floors.

This system is applicable to buildings where there are several large rooms one above another, such as factories, workshops, warehouses, &c., and by it such buildings can be warmed and ventilated better and cheaper than by any other method, the warming and the ventilating being necessarily combined, as they always ought to be.

There is a great difficulty in getting architects to provide inlets and outlets of sufficient area, and until this is done satisfactory ventilation is impossible. Architects should consult warming and ventilating engineers before the building is commenced, and not wait until it is finished before consulting an expert. In America it is no uncommon thing for the ventilating and warming to cost 25 per cent. of the cost of the whole building. How different this from the case of the architect in the West of England, who had £5 down in his quantities for the ventilation of a small town hall costing £5,000! But I do not wish it to be understood that the warming and ventilating of a building by this system would cost 25 per cent. of the whole; for instance, a building could be constructed of ordinary material in one case, and the same plan be carried out with expensive material in another, perhaps costing four times as much money, yet the apparatus would be about the same in both buildings. The size of the building to be treated should regulate the cost of the warming and ventilating apparatus, and not the material of which it is constructed.

I wish to summarise briefly, and, in so doing, to give you a few practical data that will be a guide to the size of inlets for warm air and outlets for vitiated air. In large school-rooms and public buildings, it has been found by experiment and experience that the best results are obtained when the fresh-air inlets are placed about 7 feet above the floor level, and the foul-air outlets are on the same side of the room, and at the level of the floor. In estimating the size of fresh-air inlets, we must not forget that the moment the vitiated air is drawn from the room, air will find its way through every opening in every part of the room. With the "aspiration" method of ventilating, the outlets should be larger than the inlets, and the dangers of cold draughts would then be reduced. In buildings ventilated by the "mechanical" method, the area of the inlets for fresh air should be larger than the outlets, and then the rooms are placed under a little pressure, and all the air from crevices, &c., flows outwards, and no draughts are felt.

Now you may ask—What should be the rule in estimating the area of inlets for admitting fresh air, and the area of outlets for getting rid of the impure air? These must depend mainly upon the number of persons who will occupy the room, and not to any extent upon the size of the room. For instance, take a school-

room occupied by fifty pupils; they each require not less than 30 cubic feet of air per minute, or 1,500 cubic feet amongst them. The cubical contents of such a room (say,  $30 \times 30 \times 12$ ) would be about 11,000 feet; dividing this product by 1,500 (the amount of air required per minute by the occupants of the room), we find as the quotient less than 8, which represents the number of minutes during which the air would be reasonably wholesome unrenewed. We should therefore supply, regardless of the size of the room, 1,500 cubic feet of air per minute if fifty persons occupied the room. Pupils from fifteen to twenty years of age should be supplied with 40 cubic feet of air per minute.

In estimating the rate of air motion, 5 feet per second should be the maximum. The number of square feet for the foul-air outlets can be determined by dividing 1,500 (the amount of air required per minute for fifty persons) by the amount of air that will pass out of an opening, 1 foot square, at the rate of 5 feet per second, or 300 feet per minute. Dividing 1,500 by 300, it will give 5 feet area as the size of the foul-air outlets required for a room occupied by fifty persons. In the Smead plan you will note that the area of inlet register is  $3\frac{1}{2}$  feet, while the area of each outlet register is  $2\frac{1}{2}$  feet, although only forty-four pupils are to occupy the room.

I will close with a quotation from Mr. Rufus R. Wade, the Chief of the Massachusetts Sanitary Police, to whom I am indebted for a great many notes that he gave me, and which I have made use of in this paper. He seems to have all the various systems of ventilation that have been used in America at his "fingers' ends," and he is probably one of the most reliable authorities on ventilation in the United States. He says:—"It is a curious fact that the elementary laws of public health, with which it might be supposed every intelligent community is familiar, are not generally accepted without resistance. The inertia of popular indifference is an obstacle whose power it would not be easy to over-estimate. It would seem that a crusade in the interest of securing perfect sanitary conditions in our schools would be a mighty, irresistible movement. There is certainly no organised opposition thereto, but its success demands ceaseless vigilance, and the most persistent presentation of the facts gained by daily experience and observation."

There is a great difficulty in getting archite-  
and outlets of sufficient area, and until +  
ventilation is impossible. Architec-  
and ventilating engineers before +  
not wait until it is finished

America it is no uncom-

warming to cost 25 p

How different this

England, who has

of a small town

understood +

system

buildin

and

as

by Brins' Process, Compressing

By HENRY BRIER, Mem. Inst.

and Irish Oxygen Company, Glasgow.\*

the Society, 16th December, 1891.]

in as few words as possible, showing you the manner  
in which oxygen is extracted from the atmosphere by the Brins'  
process and the advances made during the past six years.  
This process is founded upon certain properties of the metal  
barium. As first pointed out by M. Boussingault, barium oxide  
(BaO), if raised to a dull red heat, then exposed to a current of  
air, seized upon the oxygen of that air, and transformed itself into  
barium peroxide (BaO<sub>2</sub>). In the second stage, on heating the  
barium peroxide to a clear red heat, it gave up the oxygen it  
had taken, and became again barium oxide.

The M.M. Brin frères improved this process, found means to  
prevent rapid deterioration of the barium, and rendered it more  
active by peroxidising at a pressure above that of the atmosphere,  
and deoxidising with a partial vacuum. They showed their  
patented plant at work in 1885, at the Inventions Exhibition,  
South Kensington, where their enterprise was rewarded by a silver  
medal, and an English company, bearing their name, was formed  
to work their patents.

The first plant of importance, erected in Westminster, consisted  
of a furnace of 72 horizontal retorts built in two nests of 36 each.  
These retorts were of mild steel, 9 inches in diameter, by 14 feet  
long, and were charged with a total weight of 4 tons of barium  
oxide. This oxide was prepared from nitrate, by being cooked in  
crucibles for several hours at great heat, until it became hard and  
dry, very much resembling pumice-stone in appearance.

\* Mr. Brier's paper was extensively illustrated by lime-light lantern  
views on the screen. Some of his illustrations are given in the text.—*Ed.*

Much of the success of this process depends upon the preparation and subsequent treatment of the barium. Every care is taken, therefore, to render it as hard and porous as possible, and to prevent deterioration when in service. All air before being passed through the retorts is first drawn through lime and caustic soda, so as to free it from all traces of moisture and carbonic acid.

The Westminster furnace was served by four sets of pumps, each having two air cylinders, 8 inches diameter by 12 inches stroke. These pumps were capable of lifting the mercury in a vacuum tube to within  $\frac{1}{8}$ ths of an inch of the barometric height. By means of properly arranged valves and pipes, the action of the pumps was reversed in such a manner that, during the first part of an operation, air was drawn through the purifier, and was forced, at a pressure of about 15 lbs. above the atmosphere, into the retorts, the nitrogen passing into the air through a weighted escape valve. During the second stage the oxygen collected by the barium was drawn from the retorts, and forced into the gas-holder.

This plant, as at first worked upon its alternate heating-and-cooling plan, made three operations during the 24 hours, giving a total yield of 0.51 cubic foot of oxygen per lb. of barium. Of course, a great part of the barium contained in the furnace was, owing to its position in the retorts, unable to do much work, and time was lost in heating and cooling the furnace between the operations; it was soon found, therefore, that great saving could be wrought by keeping the heat constant, at about 1,500° F., and by shortening the operations to half-an-hour each. This brought the yield up to about 1.8 cubic feet of oxygen per lb. of barium per 24 hours.

While these trials were being made, others were in progress, with water-jacketed furnaces (for rapid cooling), having horizontal and vertical retorts. Several experiments were made with these furnaces, which confirmed the superiority of constant heat, and showed that, with vertical retorts, yields of 3 feet to the lb. could be obtained per 24 hours.

Furnaces with vertical retorts were then built with self-contained carbonic oxide producer. This producer, with a large combustion chamber, is placed directly in the centre of the furnace, and retorts hang in two nests on either side. The retorts are now being made of cast-iron. The air usually enters by the top of one set of retorts, and passes into the bottom of the second

set, and the current is reversed automatically at each operation by means of a small apparatus placed on the top of the furnace. By this means the barium is more uniformly employed, and is allowed from operation to operation to recover its heat. The duration of each operation is regulated, and the erection of the pumps periodically changed, by an automatic reversing gear.

With these furnaces the air on its way from the pump passed through two purifiers containing lime and caustic soda; but purifiers are also now being used on the suction side of the pump, in which case they are made after the same manner as those employed in gas-works.

The total outputs of compressed oxygen throughout the United Kingdom have been as follow :—

1887, ... ..	146,664 cubic feet.
1888, ... ..	715,730 „
1889, ... ..	1,085,240 „
1890, ... ..	1,214,500 „
1891, ... .. over	2,000,000 „

Compressing works are now in full operation in the following towns :—

1. Westminster : vertical furnace capable of yielding 5,500 cubic feet per day at work ; and an inclined furnace, capable of yielding 10,000 cubic feet, nearly completed.
2. Manchester : vertical furnace for 6,000 cubic feet per day.
3. Birmingham : vertical furnace for 10,000 cubic feet.
4. Berlin : vertical furnace for 3,000 feet.
5. New York : vertical furnace for 10,000 feet.
6. Paris : vertical furnace for 5,000 feet.

In Paris the output has been, 1887, ... ..	12,932 feet.
„ „ „ 1888, ... ..	90,000 „
„ „ „ 1889, ... ..	150,040 „
„ „ „ 1890, ... ..	207,243 „

I have not been able to obtain the Paris output for 1891, but would mention that the yield for 1890 was cut down very much on account of the old plant not being sufficiently large to meet the demand during the busy season.

In Glasgow the furnace is but small, yielding 1,500 cubic feet per day ; it was erected for experimental purposes in 1883, before vertical furnaces had come into service, and additions or improvements have been delayed in order that, when absolutely necessary, the latest improvements may be adopted. The purifier

is of the type used in gas-works, and is sufficiently large to serve for a furnace of four times the size. The pump also is larger than is at present necessary, the cylinder being 12 inches diameter by 16 inches stroke. With this pump a vacuum can be obtained within  $\frac{5}{8}$ ths of an inch of a perfect vacuum. The distributing gear is driven by hand, changes being made every fifteen minutes. At the Glasgow works the compressing power is equal to about five times the output of the present furnace.

It will, no doubt, be interesting to learn that the barium now in use in the Glasgow furnace is that with which it was originally charged in 1888.

Other plants have been erected—where compressing is not carried out—in the following works:—

Ramsgate Gas-works,	...	...	...	5,000 cubic feet.
Shrewsbury     ,,	...	...	...	5,500     ,,
Leeds Dye-works,	...	...	...	6,000     ,,
Montreal Gas-works,	...	...	...	7,000     ,,
Rochdale       ,,	...	...	...	12,000    ,,

and others are being erected at—

Duckinfield Gas-works,	...	...	...	3,500     ,,
Huddersfield       ,,	...	...	...	30,000    ,,

The total power of furnaces at present at work is 76,500 cubic feet, with 43,500 in course of construction. We shall have, therefore, very shortly a total of 120,000 cubic feet, of which 69,000 will be for gas-works, &c., and 51,000 for compressing purposes.

Oxygen for ordinary purposes is now compressed to 120 volumes, or, roughly speaking, 1,800 lbs. per square inch.

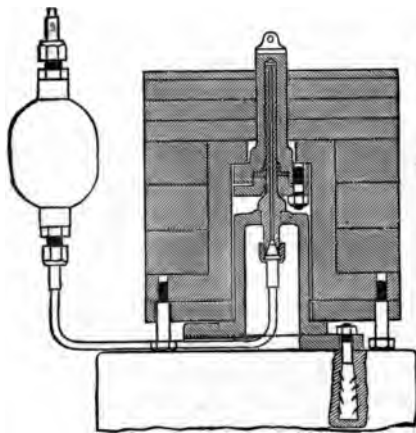
The first compressors erected in Westminster were of the three-stage type—that is to say, the gas went through three stages of compression in its passage through the pumps. The three cylinders of different diameters were cast in one piece, and were placed in a cooling tank which contained water. This plan, while working well for coal-gas, hydrogen, &c., did not give satisfaction with oxygen, for it was soon found that, for constant work, the cooling power of the water was not sufficient; and on several occasions, after running for some time, the leathers of the middle cylinder ignited spontaneously and became rapidly consumed.

Other pumps were made with separate cylinders, and long cooling coils were placed between the stages or cylinders. This entirely overcame the difficulty, and oxygen is now as easily compressed as coal-gas or hydrogen. For large yields, compressors are now

made having the first cylinder double-acting. Each end of this cylinder delivers into a common receiver, from which the second stage draws its charge.

Each compressor is fitted with a safety arrangement; some are fitted with ordinary lever safety valves, which lift or blow off at a reasonable point above the working pressure, while others have accumulators. This latter class of apparatus resembles the ordinary accumulator used for hydraulic purposes; it is clearly seen in section. (Fig. 1.) The hollow vertical plunger is coupled at its lower end to the lower side of a small reservoir, which is connected to the outlet pipe of the compressor in such a manner that, as the pressure of gas rises to its proper

FIG. 1.



limit, it presses upon the surface of the water contained in the reservoir, forces it into the accumulator, and lifts the cylinder with its load of weights as far as the three small studs shown at the bottom will allow—further movement for the time being prevented by a loose trip weight, which then becomes engaged by the heads of the studs. This first movement indicates that the cylinders being filled have received their proper charge of gas, whereupon the attendant takes the necessary steps to remove the full cylinders and open the empty ones; but should this warning, for any reason, be disregarded, the apparatus, with a little additional pressure, lifts entirely out of its place, and allows the water to escape. The gas naturally follows, frees the pump of

the pressure, and calls the attention of all persons working in the vicinity by the noise made by the escaping gas.

This apparatus has been found most efficient and reliable in its action, and several forms have been made, some of which have two trip weights instead of one. The first acts as a warning, and the second is arranged to trip and throw out of action the suction valves of the first-stage pump, and so delay the final blow-off.

Cylinders or drums, in which compressed gases are carried, differ greatly in make and quality, but the round-ended one is rapidly taking the place of all others, owing to its great strength and lightness. These cylinders are made of mild wrought steel, and are lap-welded or seamless; one end being closed, the other is swaged down into the form of a neck, into which a gun-metal valve is carefully fitted (Fig. 2). Several samples of valves will be found on the table, all of which are fitted with aluminium bronze spindles.

FIG. 2.



It will not be out of place here to point out that in Paris and London, and several other towns, steel spindles are being largely used, while in Manchester, Glasgow, and Birmingham, they are of bronze. The reason for this is two-fold; firstly, the Glasgow climate and water differ so much from those of Paris and London that it is found necessary to employ bronze, on account of the rapid manner in which the steel ones become rusted and useless. Another strong argument in favour of bronze is its safety, or inability to fire, as steel does, under certain conditions.

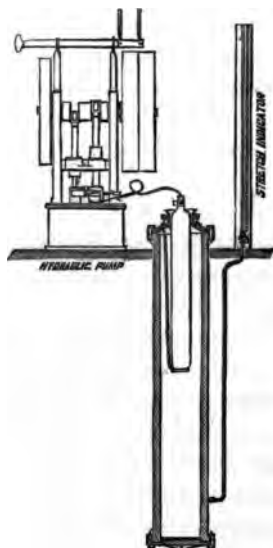
All new cylinders, lap-welded or solid-drawn, are now tested to 4,000 lbs. per square inch by hydraulic pressure, special care being taken in Glasgow to prevent the makers testing them to more than this pressure, which is considered to be a safe and sufficient test for cylinders of the section and quality of steel now employed.

It is generally considered sufficient to test cylinders by simply pressing them with water to the desired pressure; but this method, while proving a cylinder's strength, does not show its weakness; or, in other words, does not show if the pressure to

which the cylinder was subjected has done it any damage or caused "permanent set" to take place. With a view to overcoming this difficulty, several experiments were made with a testing machine (a diagram of which is shown on the screen), with which very marked results have been obtained. (Fig. 3.)

The cylinder to be tested is filled in the usual manner with water, and is placed vertically in an iron casing or envelope, which is also filled with water to the exclusion of all air. By means of a three-way valve, water pressure from any convenient source is then allowed to enter a flexible rubber-joint ring, which

FIG. 3.



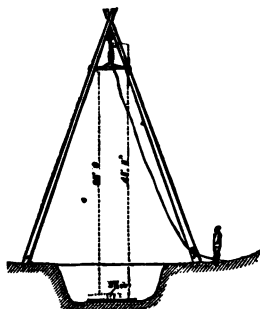
closes and makes a perfect joint round the shoulder of the cylinder in such a manner that all communication between the envelope and the atmosphere is closed, with the exception of an outlet through a small-bore glass tube, which serves as an indicator, and shows by the rise of the water within it any displacement due to stretch of the cylinder.

The mode of working is as follows :—After the cylinder has been placed in the envelope and all joints have been made, the height of water in the gauge glass is marked, the pressure is put slowly into the cylinder by means of the power pump, and elasticity is in

every case shown from the moment the first indications of pressure are given on the pressure gauge. The water in the gauge glass rises with every stroke of the pump, until the maximum pressure is reached, on release of which it falls—with good cylinders to its original position,—thus showing that the elasticity of the metal has not been passed.

In some instances, very slight permanent displacements are indicated—from  $\frac{1}{2}$  to 6 per cent. of the total,—which are not increased on repeated applications of the test, or even with slightly greater pressure. Such small variations are not considered to be stretch of metal, but are simply due to the cylinders, in the first instance, not being of such perfect form as they should be.

FIG. 4.



¶ Cylinders have been detected which, although they withstood several applications of the test, did not allow the water to return to within reasonable limits; such cylinders, of course, are not put into service. The average displacement of a 40-foot cylinder is a column of water 22 inches high by  $\frac{1}{4}$  inch diameter.

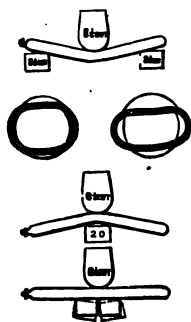
From the foregoing it will be seen that the results are sufficiently broad to be easily appreciated in the ordinary workshops by any intelligent man. Many tests for durability have been successfully applied to cylinders containing oxygen and other gases at the ordinary working pressures.

Several cylinders of different sizes were thrown from a height of 22 feet upon a paved floor, and from a height of 34 feet upon a solid earthen floor without damage.

Other more extensive trials were made as follow:—A couple of legs were erected, with the necessary lifting apparatus, snatch-

hook, &c., as shown in Fig. 4, and a drop of 35 feet was obtained by sinking a hole immediately under the legs. The cylinders experimented upon were lap-welded, and were taken without discrimination from ordinary stock, and each cylinder while being tested contained its full working charge of gas. The first cylinder experimented upon was 6 feet 6 inches long by  $5\frac{1}{2}$  inches diameter by  $\frac{1}{4}$  inch thick; it was charged with oxygen at 1,800 lbs. per square inch, and had in the usual course been tested to 3,600 lbs. per square inch by hydraulic pressure. This cylinder was dropped twice sideways, and once endwise, from a height of 35 feet, upon a block of iron 12 inches square. It was then placed across the block, and an iron weight of  $6\frac{1}{4}$  cwt. dropped on to its centre, the blow giving an impact of 15 tons, and crushing in the side as shown in Fig. 5. The cylinder was then placed with its

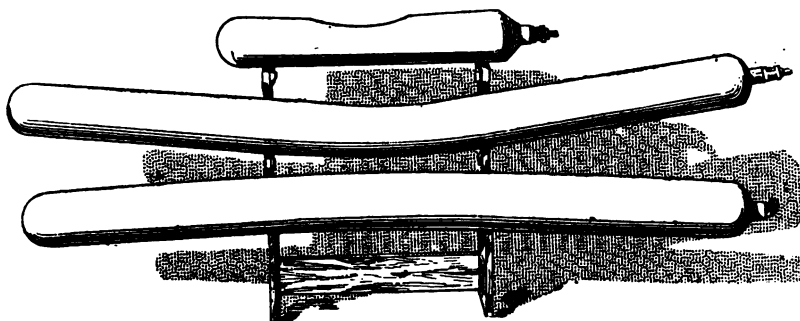
FIG. 5.



ends resting on two blocks of iron set 4 feet 1 inch apart, and the same weight again let fall, with the result that the cylinder was bent  $4\frac{1}{4}$  inches from the straight. Another cylinder of the same size was tested in the same manner, with the difference only that it was bent  $7\frac{5}{8}$  inches. A third one was dropped four times from a height of 35 feet across the iron block, so that the cylinder was struck on the same place each time, and as a result a bend of  $2\frac{1}{8}$  inches was produced. A smaller cylinder,  $5\frac{1}{2}$  inches diameter by 2 feet 7 inches long by  $\frac{1}{4}$  inch thick, containing liquefied carbonic acid, was dropped sideways and endways, 35 feet upon the block, and was then crushed, as shown in Fig. 6, by a blow of 15 tons. Another small cylinder of the same size, containing oxygen, was dropped several times upon the block (35 feet), receiving only several small dents.

Up to this point the cylinders had shown no sign of leak or distress, and, to produce fracture, the tests were carried still further. One cylinder was then destroyed by trying to straighten it,

FIG. 6.



and another, by giving it a short bend, as shown in Fig. 5, the cylinder being placed across two blocks.

Before going further I would point out that all the tests

FIG. 7.



mentioned were made with the poorest class of cylinders, being as they all were, lap-welded and only  $\frac{1}{4}$  inch thick.

**GAUGES.**—It is now well known that pressure gauges of ordinary construction, although well suited for ordinary gas or hydraulic pressure, are very liable to failure if used with oxygen: This is mainly owing to the possibility of ignition of any oil or inflammable matter which may have found its way into the gauge. To prevent the possibility of such ignitions, the gauges were, in the first instance, not tested with oil, as was usual with most gauges. Still further precautions have been taken, and the gauges are now fitted with a patent check (Figs. 7 and 8), which effectively prevents the gas entering the gauge too rapidly. The back of the

FIG. 8.



gauge also is fitted with a loose cover, which is held in a close position simply by a very delicate spring. Should the tube become leaky or damaged in any way by age or over-work, no accumulation of gas in the case would be possible.

The following experiments were made with two Bourdon gauge tubes:—One tube had been tested to 2 tons, and the other to 3 tons per square inch, and both contained traces of the oil with which they had been tested. The 2-ton tube was first fitted with a check, and was attached to a cylinder containing coal gas at 1,800 lbs. per square inch. The gas was admitted to the tube, and emptied out twice over, so as to ensure filling in with pure

gas. It was then immediately screwed on to a cylinder of oxygen, and the valve was suddenly opened, this also being repeated twice. Each time oxygen or coal-gas was admitted, the tube was found to have become slightly warm at the end, owing to compression of gas inside it. This experiment with the check was repeated about a dozen times, but nothing more than the warming was observed. The check plug was then withdrawn and the experiment was repeated as before; and in the very first experiment a "kick" was felt on the second admission of oxygen, the gauge tube becoming so hot that it could not be handled. The tube was immediately unscrewed, and emitted a strong smell of burnt oil or organic matter, and a leather packing ring used for making the joint was found to be deeply charred wherever it had been exposed to the gas. In order to verify these results, the same experiments were made with the 3-ton tube. With the check, no explosion or sign of combustion of any kind ensued; but without the check, the second admission of oxygen, after filling with coal-gas, caused an explosion, but this time so violent that the tube was completely shattered with a deafening noise. This tube, with its gun-metal fitting, will be found on the table, and it clearly shows the great force of the explosion.

These experiments clearly explain the cause of gauge explosions, and with the check-plug we appear to have a very satisfactory safeguard against them. The plug, moreover, serves to protect the gauge from great strains which would otherwise be put upon it by sudden admission of high-pressure gas, and, further, in case of the bursting of the gauge tube, would prevent gas rushing violently into the case of the gauge. One of the tubes experimented with will be found on the table. I would here mention that I am indebted to Mr. Morton Jackson, of Manchester, for the loan of this sample.

For certain purposes, regulators or reducing valves are required to reduce the high pressure of the gas as it comes from the cylinders, and deliver it at a low pressure suitable for ordinary rubber tubing. Several kinds of regulators are now in the market, a few of which I will show on the screen, and samples will be found on the table.

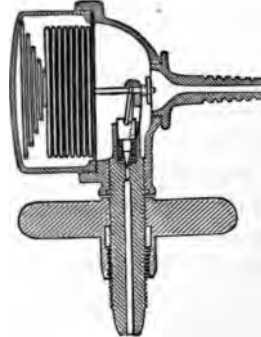
Figs. 9 and 10 show a metal-bellows regulator whose working parts are entirely of metal, and in which there is no iron or steel exposed to the action of the gases; it will be found, therefore, to be practically non-corrodible. The section (Fig. 10) will more

clearly show the action of this regulator, the lever and strut being so arranged that, as the valve comes home to its seat, more purchase is obtained by the lever, the pressure in the outlet chamber being kept very constant.

FIG. 9.



FIG. 10.



XIV.—*Some Elementary Facts regarding the Foci of Lenses, with special reference to Dallmeyer's New Tele-Photographic Lens.*

By JOHN BROWN, B.Sc., C.E.

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[Read before the Society, 13th April, 1892.]

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THE introduction of the tele-photographic lens has raised considerable interest among photographers and others. Its properties seem not to be clearly understood by many, and, indeed, are difficult to comprehend, unless some of the elementary facts relating to single lenses and combinations of two lenses are thoroughly grasped. Though the focal length is only one of eighteen things in connection with a lens enumerated by Professor S. P. Thompson,\* which might be made the subject of measurement, a large number of the others depend on it. The intention of the present paper is to try and put these facts in simple language, with as little mathematics as possible.

There are two defects of actual lenses—spherical and chromatic aberration. The first is due to the form of the lens. It can be avoided by using only the rays of light which pass through the central part of a lens. Chromatic aberration is caused by the different elementary rays of light being refracted at different angles. It may be got rid of by either making the lens truly achromatic, or using light of one refractivity, as the yellow light of sodium.

As a point to measure from, the optical centre of a single lens may be taken. It is dependent on the form of the lens only, and is defined as the point so situated that any ray passing through it will be refracted by the lens so as to emerge parallel to the original direction; that is to say, for rays passing through the optical centre, the lens acts like a parallel plate of glass. It is to be noted that the optical centre may be situated in the interior of a lens, as in the double convex and double concave lenses; on the

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\* "Measurement of Lenses," *Journal of the Society of Arts*, 27th Nov., 1891, p. 22.

surface, as in the plano-convex lens ; or outside the lens altogether, as in the meniscus lens.

A real image is one that can be shown on a screen, and is the image used in photography. A virtual image is one which can be seen by the eye, but not shown on a screen.

A convergent or positive lens, or system of lenses, is one which brings parallel rays to a point, so that a real image of a distant object is formed. This point is called the principal focus, and its distance from the optical centre of the lens is the focal length, and is considered as positive.

A divergent or negative lens, or system of lenses, is one that causes parallel rays to diverge, and the point from which they seem to diverge is the principal focus, and is on the same side of the lens as that on which the parallel rays enter. At it there is formed a virtual image of the distant object. The focal length of such a lens is the distance between the principal focus and the optical centre, and is considered as negative.

The back focus, or back focal length, is the distance between the principal focus and the surface of the lens nearest it. In the camera, it is the distance of the ground glass from the back of the lens next it. It may be equal to, less than, or greater than, the focal length. But it is the focal length which governs the size of the image formed alone. Conjugate foci are the points at which an object and its image are situated. They may be either real or virtual, as the image is real or virtual. In the case of a single lens, they are related in a very simple manner, which may be given thus:—

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

—where  $f$  is the focal length of the lens,  $u$  the distance of the object, and  $v$  the distance of the image from the optical centre ; or, in words, the sum of the reciprocals of the distance of the object and its image are equal to the reciprocal of the focal length of the lens. This fact is the basis of all tables for enlarging and reducing found in text books and photographic almanacs.

In what follows of this paper, it will be assumed that the lenses are without spherical and chromatic aberrations, and thin, so that the optical centre and surfaces may coincide ; also, that the rays are nearly parallel to the axis of the lenses, unless these conditions are expressly excluded, or the context absolutely requires this to be

done. These conditions are different from what actually occurs in photographic lenses, but are necessary to keep the theory simple.

The table at the end of the paper shows a number of the relations of single lenses and combinations of two lenses.

*The Focal Length of the Equivalent Lenses for Parallel Rays.*—

An equivalent lens has been defined thus :—"A lens is said to be equivalent to any number of lenses arranged at intervals along an axis when, if placed in a proper position, it will produce the same deviation in rays inclined at small angles to the axis of the system as would be produced by the system of lenses."\* This might be more simply expressed by saying an image of the same size as the system of lenses. It is usual to assume that the equivalent lens remains constant, whatever be the inclination of the rays to the axis, or, in other words, whatever be the distance of the object from the system of lenses.† But it has been long and well known to those who used combinations for enlarging and reducing that the distances given in the tables for the equivalent lenses were not those at which the object and its image were found in practice. This was usually attributed to errors of observation; and few, if any, were aware that the theory‡ was not quite correct. Professor Barr, when graduating his lantern slide-making camera, employed a method which did not require the focal length of the lens used to be known, and largely correcting any error from change in it for different distances. To show how the equivalent lens for parallel rays can be found, a nomenclature, due to Lord Kelvin, is convenient :—§

(1) "The principal focus of a lens is the point to which parallel incident rays are refracted; and the distance of the principal focus from the centre of the lens is called the focal length.

(2) "The refractivity of a substance is the difference between the index of refraction of the substance and unity.

(3) "The potency of a lens depends on two factors, refractivity

\* Heath's "Geometrical Optics," Cambridge University Press, 1887, p. 95.

† Thompson's "Measurement of Lenses," p. 25. Abney's "Instruction in Photography," pp. 370, 371; Piper & Carter, London, 1886.

‡ J. T. Taylor's "Optics of Photography," p. 38; Whittaker & Co., London, 1892. "American Annual of Photography," 1888, pp. 145-149.

§ Letter by Magnus Maclean in *Philosophical Magazine*, vol. 28, 1889, p. 400.

and curvature. It is equal to the product of the refractivity into the algebraic sum of the curvatures of the lens. The potency of a lens is called *convergivity* when it is for convergence, and *divergivity* when it is for divergence.

(4) "The convergence or divergence of a pencil of light is the reciprocal of the distance of the source, or of the image of the source, from the centre of the lens.

(5) "Either convergence or divergence is altered by addition or subtraction of the potency.

(6) "Convergence of a pencil of light after passing through lens = convergence of incident pencil + convergivity of lens, or = convergence of incident pencil - divergivity of lens. Divergence of a pencil of light after passing through lens = divergence of incident pencil - convergivity of lens, or = divergence of incident pencil + divergivity of lens.

(7) "The linear dimensions of object and image are directly as their distance from the centre of lens."

Note that the potency is the reciprocal of the focal length.

Suppose  $c_1c_2$  Fig. 1, are the centres of two lenses, and A a ray of light parallel to, and at unit distance from, the axis  $c_1c_2$ . (In the diagram no lenses are shown.) On meeting the first lens, it

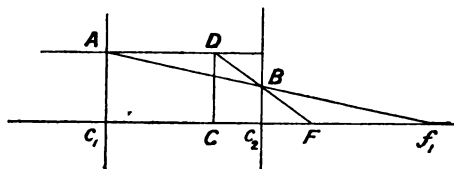


FIG. 1.

will be refracted to meet the axis at  $f_1$  (which is the focal length of the first lens), and its convergence is  $\frac{1}{f_1}$ . It meets the second lens at B, and its convergence with reference to it is  $\frac{1}{c_2f_1}$  (calling the distance between the lenses  $a$ ), then  $\frac{1}{c_2f_1} = \frac{1}{f_1 - a}$ .

The potency of the second lens is  $\frac{1}{f_2}$ , so that the convergence, after passing through it, is

$$\begin{aligned}\frac{1}{c_2 F} &= \frac{1}{f_1 - a} + \frac{1}{f_2} \\ &= \frac{f_2 + f_1 - a}{(f_1 - a)f_2} \\ c_2 F &= \frac{f_2(f_1 - a)}{f_1 + f_2 - a} = B, F.\end{aligned}$$

But  $c_2 F$  is the back focus, call it  $B, F$ . If line  $BF$  is produced to meet  $AD$  at  $D$ , and  $DC$  drawn perpendicular to the axis  $c_1 c_2$ , then  $C$  will be the optical centre of the equivalent lens for parallel rays, and its focal length ( $F$ ) will be  $CF$ .

$Bc_2 f_1$  and  $Ac_1 f_1$  are similar triangles, therefore  $\frac{Bc_2}{Ac_1} = \frac{c_2 f_1}{f_1 c_1}$  put for  $Ac_1$ ,  $c_2 f_1$ , and  $f_1 c_1$ , their values—

$$Bc_2 = \frac{f_1 - a}{f_1}$$

Again, the triangles  $DCF$  and  $Bc_2 F$  are similar, therefore  $\frac{CF}{DC} = \frac{c_2 F}{Bc_2}$  for  $DC$ ,  $c_2 F$ , and  $Bc_2$ , put their values—

$$\begin{aligned}CF &= \frac{(f_1 - a)f_2}{f_1 + f_2 - a} \div \frac{f_1 - a}{f_1} \\ &= \frac{f_1 f_2}{f_1 + f_2 - a} = F.\end{aligned}$$

These formulæ are for two positive lenses.\* A similar demonstration may be given for a positive lens and a negative lens, or it may be deduced from these formulæ by changing the sign of the focal length of the second lens from positive to negative.

A general formula for the back focus may be got by using a similar construction, thus:—

Calling  $u$  the distance of the object from the first lens, then  $\frac{1}{u}$  is the divergence; but this may be written  $-\frac{1}{u}$  convergence.

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\* Note.—In the construction it has been supposed  $a$  is less than  $f_1$ , so the correctness of the formulæ for greater values of  $a$  must not be assumed.

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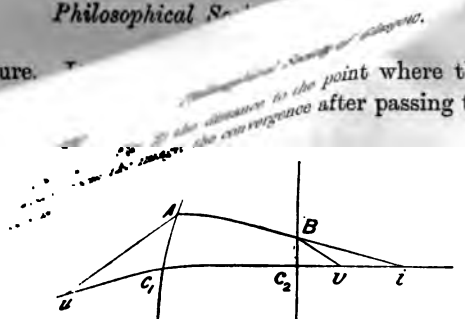


FIG. 2.

$$\frac{1}{i} = -\frac{1}{u} + \frac{1}{f_1} = \frac{u - f_1}{f_1 u}$$

$$i = \frac{f_1 u}{u - f_1}$$

The convergence with respect to the second lens is ( $v$  being the point where the image is formed by it)—

$$\frac{1}{i - a} = \frac{1}{\frac{f_1 u}{u - f_1} - a}$$

$$= \frac{u - f_1}{f_1 u - a(u - f_1)}$$

The convergence after passing through the second lens is—

$$\frac{1}{c_2 v} = \frac{u - f_1}{f_1 a - a(u - f_1)} + \frac{1}{f_2}$$

$$= \frac{f_2(u - f_1) + f_1 u - a(u - f_1)}{f_2 \{f_1 u - a(u - f_1)\}}$$

$$c_2 v = \frac{f_2 \{f_1 u - a(u - f_1)\}}{f_2(u - f_1) + f_1 u - a(u - f_1)} = \text{BF.}$$

This is the back focus for an object at distance  $u$  from front

lens. It is too complicated for much use. First let  $u$  equal  $f_1$ , then

$$\text{BF} = \frac{f_2 \{f_1 f_1 - a (f_1 - f_1)\}}{f_2 (f_1 - f_1) + f_1 f_1 - a (f_1 - f_1)} \\ = f_2$$

That is to say, the back focus is equal to the focal length of the second lens. This is clear if the figure is drawn.

Further, let the lenses both have the same focal length; then the size of the object and its image will be equal. But when this is the case with a single lens, the distance between them is equal to four times the focal length. Therefore the focal length of the

equivalent lens would be  $F^1 = \frac{2f + a}{4}$  and it would require to be

placed half-way between the lenses. The difference between the equivalent focal length for parallel rays and this is  $F - F^1 =$

$\frac{f^2}{2f - a} - \frac{2f + a}{4}$ . This shows that in this case the equivalent

lens is not always the same. If we could investigate the other cases, we would get like results. To put it in figures—

let  $f = 5$  and  $a = 1$ , then  $F - F^1 = \frac{25}{9} - \frac{11}{4} = 2.77 - 2.75 = 0.02$ .

Again, in this case, taking the second lens as the point to measure from, it can be shown that the equivalent lenses would require to be placed in different positions to produce the image at the same place as the combination; that is to say, the optical centre of the combination is not a fixed point. For parallel rays  $F - \text{BF} =$

$\frac{f^2}{2f - a} - \frac{f^2 - af}{2f - a} = \frac{af}{2f - a}$ ; and for an object at the principal

focus of either lens,  $2 F^1 - B^1 F^1 = f + \frac{1}{2}a - f = \frac{1}{2}a$ . Using

the same numbers as before,  $F - \text{BF} = \frac{5}{9}$  and  $F^1 - B^1 F^1 = \frac{1}{2}$ .

An optician wishing to produce a lens of, say, 10 inches equivalent focal length for parallel rays, has several ways of doing so.

1st. He may use a single lens, as a landscape lens.

2nd. A pair of similar lenses close together, say, 18 inches focus, and 3.6 inches apart; back focus, about 8 inches.

3rd. Two lenses, say, first focal length equal to 22 inches, and second 17 inches, placed about 1 inch apart; back focus about  $9\frac{1}{2}$  inches.

4th. By a positive of, say, 5 inches, and a negative of 6 inches focal length, and distance apart 2 inches, the back focus would be about 6 inches.

All these combinations of lenses would produce the same sized image of a distant object, if properly adjusted; but would have different equivalent focal lengths and back foci for objects at different distances.

Some cases of the effect of the difference of the distance between the lenses for two positives are here given:—

	F	BF	
1. $a = 0$ .			
Then $F = \frac{f_1 f_2}{f_1 + f_2}$		$BF = \frac{f_1 f_2}{f_1 + f_2}$	
$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$		$= F$	
2. $a > 0 < f_1$			
$F = \frac{f_1 f_2}{f_1 + f_2 - a}$		$BF = \frac{f_2 (f_1 - a)}{f_1 + f_2 - a}$	
3. $a = f_1$			
$F = \frac{f_1 f_2}{f_1 + f_2 - f_1}$		$BF = \frac{f_2 (f_1 - f_1)}{f_1 + f_2 - f_1}$	
$= f_2$		$= 0$	

Case 2nd is that of the photographic lenses of the rectilinear type, as the distance increases the focal length increases from that of case 1 (the reciprocal of the equivalent focal length is equal to the sum of the reciprocals of the focal lengths of the lenses) to that of case 3 (the focal length of the first lens); and the back focus decreases from the equivalent focus, as in case 1, to nothing, as in case 3. Thus, the available difference of focus with this construction is the difference between the focal length of the first

lens and the sum of the reciprocals of the lenses. To put it into figures—if there are two positive lenses with focal length 18 inches—

$$\frac{1}{F''} = \frac{1}{18} + \frac{1}{18} = \frac{2}{18} = \frac{1}{9}$$

$$F'' = 9 \text{ inches, and } B''F'' = F'' = 9 \text{ inches.}$$

This is the shortest available focal length.

$$F = 18 \text{ and } BF = 0.$$

This is the longest available focal length.

Some cases of the effect of change of distance in the case of a positive lens combined with a negative one:

4. Let  $a = 0$ .

$$F = \frac{-f_2 f_1}{f_1 - f_2} \qquad BF = \frac{-f_2 f_1}{f_1 - f_2}$$

$$\frac{1}{F} = \frac{1}{f_1} - \frac{1}{f_2} \qquad = F, \text{ and follows the same rule.}$$

this + when  $f_1 < f_2$

„ - „  $f_1 > f_2$

5. Let  $a < 0 < f_1 - f_2$

$$F = \frac{-f_2 f_1}{f_1 - f_2 - a} \qquad BF = \frac{-f_2 (f_1 - a)}{f_1 - f_2 - a}$$

F is negative. BF is negative.

6. Let  $a = f_1 - f_2$

$$F = \frac{-f_2 f_1}{f_1 - f_2 - f_1 + f_2} \qquad BF = \frac{-f_2 (f_1 - f_1 + f_2)}{f_1 - f_2 - f_1 + f_2}$$

$= \alpha \qquad \qquad \qquad = \alpha$

7. Let  $a > f_1 - f_2 < f_1$

$$F = \frac{-f_2 f_1}{f_1 - f_2 - a} \qquad BF = \frac{-f_2 (f_1 - a)}{f_1 - f_2 - a}$$

This is positive, as  $f_1 - f_2 - a$  is negative. This is positive.

8. Let  $a = f_1$

$$F = \frac{-f_2 f_1}{f_1 - f_2 - f_1} = \frac{-f_2 f_1}{-f_2} = f_1$$

$$BF = \frac{-f_2 (f_1 - f_1)}{f_1 - f_2 - f_1} = \frac{0}{0} = 0$$

Case 7 is that of the photographic lenses of this type, as  $a$  increases from  $f_1 - f_2$  (case 6) to  $f_1$  (case 8), the focus decreases from infinity to that of the positive lens. Thus we have command of a very great number of focal lengths in a short change of tube length. The back focus decreases faster than the focal length, thus giving a long focus lens with a short back focus comparatively. It is this property that gives the tele-photographic lens its peculiar advantages. To put the case in numbers, let  $f_1 = 7$ ,  $-f_2 = -6$ , then  $-a = 7 - 6 = 1$ .

$$F = \frac{-6 \times 7}{7 - 6 - 1} = \frac{-6 \times 7}{0} = \infty$$

$$BF = \frac{-6(7 - 1)}{7 - 6 - 1} = \frac{-6 \times 6}{0} = \infty$$

This would be the same as an opera glass. Then let  $a = 7$

$$F = \frac{-6 \times 7}{7 - 6 - 7} = 7. \quad BF = \frac{-6(7 - 7)}{7 - 6 - 7} = 0.$$

Thus, in a difference of tube length of 6 inches, we pass from an equivalent focal length, for parallel rays, equal to infinity, and the back focus, also infinite, to an equivalent focal length of 7 inches, and no length of back focus. There can be produced any focal length between these, say, 21 inches—

$$F = 21 = \frac{-6 \times 7}{7 - 6 - a} \quad BF = \frac{-6(7 - 3)}{7 - 6 - 3}$$

$$= \frac{42}{a - 1} \quad = \frac{-6 \times 4}{-2}$$

$$1 = \frac{2}{a - 1} \quad = 6 \times 2$$

$$a = 2 + 1 = 3 \text{ inches.} \quad = 12 \text{ inches.}$$

To sum up: First, in regard to the back focus for parallel rays. It may be greater than the focal length in the case of a deep meniscus lens (wide-angled landscape), less than the equivalent focal length in the case of the doublet, composed of two positive lenses (rectilinear type), but in their case it is greater than the difference between the focal length and distance between the lenses. In the combination of a positive lens and a negative lens (Steinheil's anti-planat and Dallmeyer's tele-photographic), it is not only less than the equivalent focus, but less than the difference between the equivalent focus and the distance between the lenses.

Then, with regard to focal length, without altering the nature of a single lens we cannot change its focal length. Thus, we cannot match, for stereoscopic purposes, two unequal common landscape lenses. With the combination of two positive lenses, by altering the tube length between nothing and the focal length of the first lens, we may have any focal length between that which is the reciprocal of the sum of the reciprocals of the lenses, and the focal length of the first lens. This gives the power to match lenses of the rectilinear type, but care would require to be exercised that the systems of lenses were nearly similar, or the back focus and foci for objects at different distances would not be the same in both systems. Then, in the case of a positive lens combined with a negative, we have a very great power of altering the equivalent focal length, almost unlimited, without great tube length, but other factors limit its use.

One word about the Dallmeyer tele-photographic lens. Though it has a short back focus, the focal length is really long, so that the distance between an object and its image is the same as it would be if a single lens of corresponding focal length were used. It will not enable large-sized portraits to be taken in a shorter studio than if a portrait or rectilinear lens of similar actual focal length were used; but it will enable a shorter camera to be employed. This is one of its great advantages, and will be of great use for out-door work, combined with the power of varying the focal length. Those who have used a long-focus camera know the trouble and labour of transporting it, and long-focus lenses are often desirable for artistic work.

TABLE OF FOCI, &amp;c.

No.	Type Lens.	Actual Photographic Lenses.	Equivalent Focus for Parallel Rays.	Back Focus for Parallel Rays.	Optical Centre.	Rule for Conjugate Foci.	Notes.
1.	Single Positive Lens.	Landscape Lenses	$f$	$f$	A fixed point, dependent on form of Lens.	$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$	Real, unless $a$ less than $f$
2.	Single Negative Lens.	...	$-f$	None.	A fixed point, dependent on form of Lens.	$\frac{1}{f} = \frac{1}{u} - \frac{1}{v}$	Image virtual.
3.	Doublet Positive Lenses.	Rectilinear Lenses	$F = \frac{f_1 f_2}{f_1 + f_2 - a}$	$BF = \frac{f_2 (f_1 - a)}{f_1 + f_2 - a}$	Not a fixed point, usually between Lenses.	No simple rule.	Lens positive, $a = 0$ till $a = f_1$
4.	Doublet Positive Lens and Negative Lens.	Steinheil's Antiplanat. Dallmeyer's Telephotographic.	$F = \frac{-f_2 f}{f_1 - f_2 - a}$	$BF = \frac{-f_2 (f_1 - a)}{f_1 - f_2 - a}$	Not a fixed point, usually in front of Positive Lens.	No simple rule.	Lens positive when $a > f_1 - f_2$ till $a = f_1$

XV.—*On the Causes of the Spread of Pulmonary Consumption and other Tubercular Diseases, and on the means which may be taken to prevent their Dissemination.* By EBEN. DUNCAN, M.D., Physician to the Victoria Infirmary; Examiner in Clinical Medicine in the University of Glasgow; and Vice-President of the Sanitary Association of Scotland.

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[Read before the Society, 30th March, 1892.]

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THE chief members of the group of tubercular diseases are—

1. Phthisis pulmonalis (consumption of the lungs);
2. Tabes mesenterica (consumption of the bowels);
3. Tubercular meningitis (water in the head); and
4. Scrofulous disease, so common in the glands, the bones, and the joints.

But, in addition to these, we have a multitude of diseases in all parts of the bodies of men and of the lower animals in which tubercular disease is the essential element. There is no other class of ailment affecting animal life so wide-spread and so destructive. The experiments of Koch, the discoverer of the tubercle bacillus, have proved not only the presence of that micro-organism in every one of these tubercular diseases, but also the important fact that by the inoculation of a pure cultivation of the bacillus, grown in coagulated blood serum, diseases exactly similar can be induced in the bodies of all warm-blooded animals. Koch's experiments have been confirmed by numerous reliable men in all parts of the world. There is, therefore, now no reasonable ground for doubting Koch's statement that, in whatever organ or tissue tubercular or scrofulous disease may be found, the actual exciting cause of the disease is the tubercle bacillus.

This bacillus is a micro-organism which is seen under a high power of the microscope as a rod-like body measuring in length

and curvature. It is equal to the product of the refractivity into the algebraic sum of the curvatures of the lens. The potency of a lens is called convergivity when it is for convergence, and divergivity when it is for divergence.

(4) "The convergence or divergence of a pencil of light is the reciprocal of the distance of the source, or of the image of the source, from the centre of the lens.

(5) "Either convergence or divergence is altered by addition or subtraction of the potency.

(6) "Convergence of a pencil of light after passing through lens = convergence of incident pencil + convergivity of lens, or = convergence of incident pencil - divergivity of lens. Divergence of a pencil of light after passing through lens = divergence of incident pencil - convergivity of lens, or = divergence of incident pencil + divergivity of lens.

(7) "The linear dimensions of object and image are directly as their distance from the centre of lens."

Note that the potency is the reciprocal of the focal length.

Suppose  $c_1c_2$  Fig. 1, are the centres of two lenses, and A a ray of light parallel to, and at unit distance from, the axis  $c_1c_2$ . (In the diagram no lenses are shown.) On meeting the first lens, it

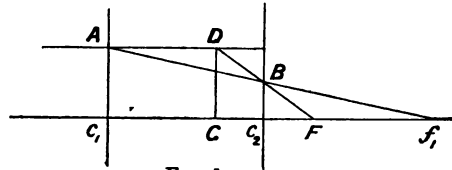


FIG. 1.

will be refracted to meet the axis at  $f_1$  (which is the focal length of the first lens), and its convergence is  $\frac{1}{f_1}$ . It meets the second lens at B, and its convergence with reference to it is  $\frac{1}{c_2f_1}$  (calling the distance between the lenses  $a$ ), then  $\frac{1}{c_2f_1} = \frac{1}{f_1 - a}$ .

The potency of the second lens is  $\frac{1}{f_2}$ , so that the convergence, after passing through it, is

$$\begin{aligned}\frac{1}{c_2 F} &= \frac{1}{f_1 - a} + \frac{1}{f_2} \\ &= \frac{f_2 + f_1 - a}{(f_1 - a)f_2} \\ c_2 F &= \frac{f_2(f_1 - a)}{f_1 + f_2 - a} = B, F.\end{aligned}$$

But  $c_2 F$  is the back focus, call it B, F. If line BF is produced to meet AD at D, and DC drawn perpendicular to the axis  $c_1 c_2$ , then C will be the optical centre of the equivalent lens for parallel rays, and its focal length (F) will be CF.

$Bc_2 f_1$  and  $Ac_1 f_1$  are similar triangles, therefore  $\frac{Bc_2}{Ac_1} = \frac{c_2 f_1}{f_1 c_1}$ , put for  $Ac_1$ ,  $c_2 f_1$ , and  $f_1 c_1$ , their values—

$$Bc_2 = \frac{f_1 - a}{f_1}$$

Again, the triangles DCF and  $Bc_2 F$  are similar, therefore  $\frac{CF}{DC} = \frac{c_2 F}{Bc_2}$  for DC,  $c_2 F$ , and  $Bc_2$ , put their values—

$$\begin{aligned}CF &= \frac{(f_1 - a)f_2}{f_1 + f_2 - a} \div \frac{f_1 - a}{f_1} \\ &= \frac{f_1 f_2}{f_1 + f_2 - a} = F.\end{aligned}$$

These formulæ are for two positive lenses.\* A similar demonstration may be given for a positive lens and a negative lens, or it may be deduced from these formulæ by changing the sign of the focal length of the second lens from positive to negative.

A general formula for the back focus may be got by using a similar construction, thus:—

Calling  $u$  the distance of the object from the first lens, then  $\frac{1}{u}$  is the divergence; but this may be written  $-\frac{1}{u}$  convergence.

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\* Note.—In the construction it has been supposed  $a$  is less than  $f_1$ , so the correctness of the formulæ for greater values of  $a$  must not be assumed.

Calling  $i$  (Fig. 2) the distance to the point where the first lens would form the image, the convergence after passing through this lens is—

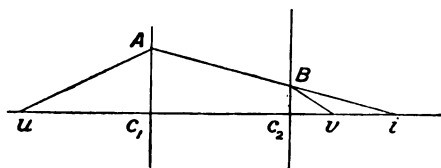


FIG. 2.

$$\frac{1}{i} = -\frac{1}{u} + \frac{1}{f_1} = \frac{u - f_1}{f_1 u}$$

$$i = \frac{f_1 u}{u - f_1}$$

The convergence with respect to the second lens is ( $v$  being the point where the image is formed by it)—

$$\frac{1}{i - a} = \frac{1}{\frac{f_1 u}{u - f_1} - a}$$

$$= \frac{u - f_1}{f_1 u - a(u - f_1)}$$

The convergence after passing through the second lens is—

$$\frac{1}{c_2 v} = \frac{u - f_1}{f_1 a - a(u - f_1)} + \frac{1}{f_2}$$

$$= \frac{f_2(u - f_1) + f_1 u - a(u - f_1)}{f_2 \{f_1 u - a(u - f_1)\}}$$

$$c_2 v = \frac{f_2 \{f_1 u - a(u - f_1)\}}{f_2(u - f_1) + f_1 u - a(u - f_1)} = \text{BF.}$$

This is the back focus for an object at distance  $u$  from front

lens. It is too complicated for much use. First let  $u$  equal  $f_1$ , then

$$\begin{aligned} \text{BF} &= \frac{f_2 \{f_1 f_1 - a (f_1 - f_1)\}}{f_2 (f_1 - f_1) + f_1 f_1 - a (f_1 - f_1)} \\ &= f_2 \end{aligned}$$

That is to say, the back focus is equal to the focal length of the second lens. This is clear if the figure is drawn.

Further, let the lenses both have the same focal length; then the size of the object and its image will be equal. But when this is the case with a single lens, the distance between them is equal to four times the focal length. Therefore the focal length of the

equivalent lens would be  $F^1 = \frac{2f + a}{4}$  and it would require to be

placed half-way between the lenses. The difference between the equivalent focal length for parallel rays and this is  $F - F^1 =$

$\frac{f^2}{2f - a} - \frac{2f + a}{4}$ . This shows that in this case the equivalent

lens is not always the same. If we could investigate the other cases, we would get like results. To put it in figures—

let  $f=5$  and  $a=1$ , then  $F - F^1 = \frac{25}{9} - \frac{11}{4} = 2.77 - 2.75 = 0.02$ .

Again, in this case, taking the second lens as the point to measure from, it can be shown that the equivalent lenses would require to be placed in different positions to produce the image at the same place as the combination; that is to say, the optical centre of the combination is not a fixed point. For parallel rays  $F - \text{BF} =$

$\frac{f^2}{2f - a} - \frac{f^2 - af}{2f - a} = \frac{af}{2f - a}$ ; and for an object at the principal

focus of either lens,  $2 F^1 - B^1 F^1 = f + \frac{1}{2}a - f = \frac{1}{2}a$ . Using

the same numbers as before,  $F - \text{BF} = \frac{5}{9}$  and  $F^1 - B^1 F^1 = \frac{1}{2}$ .

An optician wishing to produce a lens of, say, 10 inches equivalent focal length for parallel rays, has several ways of doing so.

1st. He may use a single lens, as a landscape lens.

2nd. A pair of similar lenses close together, say, 18 inches focus, and 3.6 inches apart; back focus, about 8 inches.

3rd. Two lenses, say, first focal length equal to 22 inches, and second 17 inches, placed about 1 inch apart; back focus about  $9\frac{1}{2}$  inches.

4th. By a positive of, say, 5 inches, and a negative of 6 inches focal length, and distance apart 2 inches, the back focus would be about 6 inches.

All these combinations of lenses would produce the same sized image of a distant object, if properly adjusted; but would have different equivalent focal lengths and back foci for objects at different distances.

Some cases of the effect of the difference of the distance between the lenses for two positives are here given:—

F	BF
<p>1. <math>a = 0</math>.</p> <p style="text-align: center;">Then <math>F = \frac{f_1 f_2}{f_1 + f_2}</math></p> <p style="text-align: center;"><math>\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}</math></p>	<p style="text-align: center;"><math>BF = \frac{f_1 f_2}{f_1 + f_2}</math></p> <p style="text-align: center;"><math>= F</math></p>
<p>2. <math>a &gt; 0 &lt; f_1</math></p> <p style="text-align: center;"><math>F = \frac{f_1 f_2}{f_1 + f_2 - a}</math></p>	<p style="text-align: center;"><math>BF = \frac{f_2 (f_1 - a)}{f_1 + f_2 - a}</math></p>
<p>3. <math>a = f_1</math></p> <p style="text-align: center;"><math>F = \frac{f_1 f_2}{f_1 + f_2 - f_1}</math></p> <p style="text-align: center;"><math>= f_2</math></p>	<p style="text-align: center;"><math>BF = \frac{f_2 (f_1 - f_1)}{f_1 + f_2 - f_1}</math></p> <p style="text-align: center;"><math>= 0</math></p>

Case 2nd is that of the photographic lenses of the rectilinear type, as the distance increases the focal length increases from that of case 1 (the reciprocal of the equivalent focal length is equal to the sum of the reciprocals of the focal lengths of the lenses) to that of case 3 (the focal length of the first lens); and the back focus decreases from the equivalent focus, as in case 1, to nothing, as in case 3. Thus, the available difference of focus with this construction is the difference between the focal length of the first

lens and the sum of the reciprocals of the lenses. To put it into figures—if there are two positive lenses with focal length 18 inches—

$$\frac{1}{F''} = \frac{1}{18} + \frac{1}{18} = \frac{2}{18} = \frac{1}{9}$$

$F'' = 9$  inches, and  $B''F'' = F'' = 9$  inches.

This is the shortest available focal length.

$$F = 18 \text{ and } BF = 0.$$

This is the longest available focal length.

Some cases of the effect of change of distance in the case of a positive lens combined with a negative one:

4. Let  $a = 0$ .

$$F = \frac{-f_2 f_1}{f_1 - f_2} \quad BF = \frac{-f_2 f_1}{f_1 - f_2}$$

$$\frac{1}{F} = \frac{1}{f_1} - \frac{1}{f_2} \quad = F, \text{ and follows the same rule.}$$

this + when  $f_1 < f_2$   
 „ - „  $f_1 > f_2$

5. Let  $a < 0 < f_1 - f_2$

$$F = \frac{-f_2 f_1}{f_1 - f_2 - a} \quad BF = \frac{-f_2 (f_1 - a)}{f_1 - f_2 - a}$$

$F$  is negative.  $BF$  is negative.

6. Let  $a = f_1 - f_2$

$$F = \frac{-f_2 f_1}{f_1 - f_2 - f_1 + f_2} \quad BF = \frac{-f_2 (f_1 - f_1 + f_2)}{f_1 - f_2 - f_1 + f_2}$$

$$= \infty \quad = \infty$$

7. Let  $a > f_1 - f_2 < f_1$

$$F = \frac{-f_2 f_1}{f_1 - f_2 - a} \quad BF = \frac{-f_2 (f_1 - a)}{f_1 - f_2 - a}$$

This is positive, as  $f_1 - f_2 - a$  is negative. This is positive.

8. Let  $a = f_1$

$$F = \frac{-f_2 f_1}{f_1 - f_2 - f_1} = \frac{-f_2 f_1}{-f_2} = f_1$$

$$BF = \frac{-f_2 (f_1 - f_1)}{f_1 - f_2 - f_1} = \frac{0}{0}$$

Case 7 is that of the photographic lenses of this type, as  $a$  increases from  $f_1 - f_2$  (case 6) to  $f_1$  (case 8), the focus decreases from infinity to that of the positive lens. Thus we have command of a very great number of focal lengths in a short change of tube length. The back focus decreases faster than the focal length, thus giving a long focus lens with a short back focus comparatively. It is this property that gives the tele-photographic lens its peculiar advantages. To put the case in numbers, let  $f_1 = 7$ ,  $-f_2 = -6$ , then  $-a = 7 - 6 = 1$ .

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Thus, in a difference of tube length of 6 inches, we pass from an equivalent focal length, for parallel rays, equal to infinity, and the back focus, also infinite, to an equivalent focal length of 7 inches, and no length of back focus. There can be produced any focal length between these, say, 21 inches—

$$F = 21 = \frac{-6 \times 7}{7 - 6 - a}$$

$$BF = \frac{-6(7 - 3)}{7 - 6 - 3}$$

$$= \frac{42}{a - 1} = \frac{-6 \times 4}{-2}$$

$$1 = \frac{2}{a - 1} = 6 \times 2$$

$$a = 2 + 1 = 3 \text{ inches.} \quad = 12 \text{ inches.}$$

To sum up: First, in regard to the back focus for parallel rays. It may be greater than the focal length in the case of a deep meniscus lens (wide-angled landscape), less than the equivalent focal length in the case of the doublet, composed of two positive lenses (rectilinear type), but in their case it is greater than the difference between the focal length and distance between the lenses. In the combination of a positive lens and a negative lens (Steinheil's anti-planat and Dallmeyer's tele-photographic), it is not only less than the equivalent focus, but less than the difference between the equivalent focus and the distance between the lenses.

Then, with regard to focal length, without altering the nature of a single lens we cannot change its focal length. Thus, we cannot match, for stereoscopic purposes, two unequal common landscape lenses. With the combination of two positive lenses, by altering the tube length between nothing and the focal length of the first lens, we may have any focal length between that which is the reciprocal of the sum of the reciprocals of the lenses, and the focal length of the first lens. This gives the power to match lenses of the rectilinear type, but care would require to be exercised that the systems of lenses were nearly similar, or the back focus and foci for objects at different distances would not be the same in both systems. Then, in the case of a positive lens combined with a negative, we have a very great power of altering the equivalent focal length, almost unlimited, without great tube length, but other factors limit its use.

One word about the Dallmeyer tele-photographic lens. Though it has a short back focus, the focal length is really long, so that the distance between an object and its image is the same as it would be if a single lens of corresponding focal length were used. It will not enable large-sized portraits to be taken in a shorter studio than if a portrait or rectilinear lens of similar actual focal length were used; but it will enable a shorter camera to be employed. This is one of its great advantages, and will be of great use for out-door work, combined with the power of varying the focal length. Those who have used a long-focus camera know the trouble and labour of transporting it, and long-focus lenses are often desirable for artistic work.

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2.	Single Negative Lens.	...	$-f$	None.	A fixed point, dependent on form of Lens.	$\frac{1}{f} = \frac{1}{u} - \frac{1}{v}$	Image virtual.
3.	Doublet Positive Lenses.	Rectilinear Lenses	$F = \frac{f_1 f_2}{f_1 + f_2 - a}$	$BF = \frac{f_2 (f_1 - a)}{f_1 + f_2 - a}$	Not a fixed point, usually between Lenses.	No simple rule.	Lens positive, $a = 0$ till $a = f_1$
4.	Doublet Positive Lens and Negative Lens.	Steinheil's Antiplanat. Dallmeyer's Telephotographic.	$F = \frac{-f_2 f}{f_1 - f_2 - a}$	$BF = \frac{-f_2 (f_1 - a)}{f_1 - f_2 - a}$	Not a fixed point, usually in front of Positive Lens.	No simple rule.	Lens positive when $a > f_1 - f_2$ till $a = f_1$

XV.—*On the Causes of the Spread of Pulmonary Consumption and other Tubercular Diseases, and on the means which may be taken to prevent their Dissemination.* By EBEN. DUNCAN, M.D., Physician to the Victoria Infirmary; Examiner in Clinical Medicine in the University of Glasgow; and Vice-President of the Sanitary Association of Scotland.

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[Read before the Society, 30th March, 1892.]

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THE chief members of the group of tubercular diseases are—

1. Phthisis pulmonalis (consumption of the lungs);
2. Tabes mesenterica (consumption of the bowels);
3. Tubercular meningitis (water in the head); and
4. Scrofulous disease, so common in the glands, the bones, and the joints.

But, in addition to these, we have a multitude of diseases in all parts of the bodies of men and of the lower animals in which tubercular disease is the essential element. There is no other class of ailment affecting animal life so wide-spread and so destructive. The experiments of Koch, the discoverer of the tubercle bacillus, have proved not only the presence of that micro-organism in every one of these tubercular diseases, but also the important fact that by the inoculation of a pure cultivation of the bacillus, grown in coagulated blood serum, diseases exactly similar can be induced in the bodies of all warm-blooded animals. Koch's experiments have been confirmed by numerous reliable men in all parts of the world. There is, therefore, now no reasonable ground for doubting Koch's statement that, in whatever organ or tissue tubercular or scrofulous disease may be found, the actual exciting cause of the disease is the tubercle bacillus.

This bacillus is a micro-organism which is seen under a high power of the microscope as a rod-like body measuring in length

from one-fourth to one-half of the diameter of a red blood corpuscle—that is to say,  $\frac{1}{8000}$  to  $\frac{1}{12000}$  of an inch.

These minute rod-like bodies are not quite straight, but are curved in form, and often show slight breaks or bends in their contour. It is now ascertained that they are true parasites, and complete the whole cycle of their life-history in the body of their host. They propagate by resting spores (two to six in number), which retain their vitality with great tenacity even outside of the body, and under circumstances most unfavourable to their development. It has been proved by inoculation experiments that the tubercle spores, in such matter as dried sputum of phthisical patients, may retain their virulence for a period of six months. While the bacilli and their spores retain their vitality they cannot develop and propagate themselves otherwise than within the bodies of human beings or of other warm-blooded animals. It is only with the greatest care that they can be grown experimentally on such organic matters as coagulated blood serum when specially prepared and constantly kept about the same temperature as the human body, and, further, when they are protected from the other bacteria, the spores of which float in the dust of the atmosphere. Under these experimental circumstances it is found that the spores of the tubercle bacillus grow very slowly, and only come to full maturity in from three to four weeks. From the great difficulty experienced in growing them experimentally, we may conclude that the tubercle bacilli found in nature have all been grown in the body of some animal suffering from tuberculosis. Tubercular diseases are, therefore, typically communicable and contagious diseases. If, then, their cause, the tubercle bacillus, cannot come from any other source than the body of some animal affected by tuberculosis, it follows (1) that if we could destroy all the animals in the world at present suffering from tuberculosis, and all their diseased excreta, we would at once abolish tubercular diseases; or (2) if we could render the body of a man or of an animal an unsuitable soil for the growth of the parasite, then that man or that animal would be as completely protected from tubercular disease as if we had destroyed the whole race of tubercle bacilli.

#### DEATH-RATE FROM TUBERCULAR DISEASES IN GREAT BRITAIN.

As shown by the returns of the Registrar-General, twenty years ago, the annual death-rate from tubercular diseases in Scotland

averaged 17·29 per cent. of the total deaths. In the last published volume of abstracts of mortality (1889) this average death-rate was shown to have fallen to 13·4.

The fall in the death-rate from this class of diseases during the past twenty years is equally marked in England. There, in the five years 1866-70, the average annual death-rate from tubercular diseases was 3,199 per millon, whereas in the years 1886-90 the rate per million had fallen to 2,321.

At the present rate of mortality I calculate that, in round numbers, 10,000 persons die annually from these diseases in Scotland, and 67,000 persons in England, giving a total of 77,000 deaths annually from tubercular disease in Great Britain. The majority of these deaths are due to phthisis pulmonalis, popularly known as consumption of the lungs. I here give the actual number of deaths for one year, as stated in the latest reports of the Registrar-Generals of England and Scotland :—

	Scotland.	England.	Total.
Deaths from all tubercular diseases, .	9,722	67,528	77,250
Deaths from phthisis pulmonalis, .	7,098	47,634	54,732

Even this large number does not suffice to indicate the disastrous effects of these maladies. Every physician knows that a large proportion of the numerous deaths registered under the names of bronchitis and inflammation of the lungs are really due to tubercle. Apart altogether from errors due to difficulty of diagnosis, where there is any loophole by which it is possible to escape from the stigma of tubercular taint in a family, it is eagerly seized upon, and death is attributed by the relatives to any other cause that can be made to look feasible.

Life insurance companies, therefore, believing in the heredity of phthisis, inquire most carefully into such indefinite causes of death in relatives as childbed, &c., with the result that in many cases the death so registered turns out to have been the termination of a long-standing illness, which had all the symptoms of consumption of the lungs. Taking all these facts into consideration, I think I am much nearer the truth when I state the annual death-rate from tubercular disease in Great Britain at 100,000. We have no means of ascertaining with accuracy the number of persons who suffer from tubercular diseases in proportion to the number who die of these maladies. But, considering the chronic character of tubercular ailments (most of them lasting for years, and many of them ending in recovery), I think I am justified in

stating that for every death there are at least ten persons suffering from some form of tubercular ailment. I thus arrive at the conclusion that, as the average annual death-rate is about 100,000, there is an average number of 1,000,000 persons in Great Britain constantly suffering from the dangerous effects of the tubercle bacillus in some form. Out of that number 700,000 persons are suffering from consumption of the lungs.

The death-rate from tubercular diseases among the domestic animals cannot be accurately ascertained, but from the Report of the Parliamentary Committee on Pleuro-pneumonia and Tuberculosis, published in 1888, and from other sources, I think it highly probable that, in proportion to their numbers, the amount of tuberculosis among dairy cattle is even greater than it is in the human population. The grounds on which I found my statement as to the great prevalence of tuberculosis in dairy cattle are as follow :—

1. At a meeting of the Sanitary Association of Scotland, held in Edinburgh last September, Professor M'Fadyean, of the Royal Veterinary College, stated that he found 23 per cent. of the milk cows which he had an opportunity of examining *post-mortem* were tubercular. He further stated that about 20 per cent of all the dairy cows in Scotland would probably be found to be tubercular, and that in this respect the country dairies were worse than the town dairies.

2. At the same meeting Principal Whalley stated that a short time previously he had ordered the slaughter of eleven perfectly healthy-looking cows on account of pleuro-pneumonia, and that seven of these were found to be tubercular.

3. In the Report of the Royal Commission on Pleuro-pneumonia and Tuberculosis, Mr. John Spier, of Newton Farm, stated to the Committee that two local authorities in his neighbourhood, after examination of all the herds of cattle in Paisley and Glasgow, came to the conclusion that 30 per cent were more or less affected with tuberculosis.

4. Mr. Cornelius Cunningham, V.S., stated on evidence to the same Committee that he had occasion to kill sixteen Ayrshire cattle, and that of these four were tubercular—that is to say, 25 per cent. Some of these showed no signs of it whatever during life. Professor M'Call stated that in a farm near Glasgow twenty-five Ayrshire cows were turned out to the fields in May, and twelve of these

died from tuberculosis before the New Year, and several others showed symptoms.

The prevalence of tubercular diseases among domestic animals is a serious danger to the public health, because there is now no doubt that the flesh and milk of tubercular animals are important factors in spreading tuberculosis amongst the human population. It is now a well ascertained fact that tuberculosis is common not only among bovines, but also in swine, fowls, and other domestic animals, the flesh of which may convey the disease to man.

According to the Report of the Parliamentary Committee already referred to, the order of liability to tuberculosis among animals is as follows:—(1) Man; (2) milch cows; (3) fowls; (4) rodents; (5) pigs; (6) goats; (7) sheep; (8) horses; (9) carnivora, dog and cat, &c., rarely.

There are, in round numbers, 2,400,000 milk cows in Great Britain, and if Professor M'Fadyean's estimate is correct, nearly 500,000 of these are tubercular, and are actively disseminating the tubercle bacillus or its spores by their milk when living, and by their flesh when dead.

More than two thousand years ago the doctrine of the contagious nature of pulmonary consumption, which is the chief member of the group of tubercular diseases, was referred to by Aristotle as a commonly acknowledged doctrine among the Greeks of his day. In the second century of the Christian era, Galen, the most eminent physician of his time, taught the same doctrine in Rome, and cautioned attendants on consumptive patients against the danger of being constantly about their persons through the whole course of the disease. In more modern times the Italians, the Spaniards, and the Portuguese have been the chief supporters of this view. I extract the following from the returns to the Investigation Committee of the British Medical Association on the communicability of phthisis. Dr. John Gason, of Rome, writes:—"So prevalent in Rome is the idea of its communicability, that at the Hospital of St. John Lateran for Women there is an upper ward reserved solely for such cases, which will not be admitted into the general wards. When a poor person dies in Rome of that disease, at their own home, the family almost invariably leave it, and go into another apartment." Dr. Underhill writes:—"Some years ago, when travelling through country districts in Spain, I found a common notion prevailing among the lower orders that phthisis

was contagious. They never used a room where a person had died of phthisis without first thoroughly disinfecting it." Dr. Brant, of Oporto, writes :—" Among the Portuguese and Spaniards it is a popular belief that phthisis is contagious. During illness a separate set of crockery, knives and forks, spoons, and bedclothes, is put aside for their especial use. After death, bed and linen are destroyed." In this country many individual physicians have acknowledged the doctrine of contagion in a modified and hesitating manner. For instance, in the early part of this century, Dr. John Mason Good, in his "Study of Medicine," writes :—"I have myself been witness to various cases which could not be ascribed to any other cause." . . . "The disease, however, is but slightly contagious, admitting it to be so at all, and seems to demand long and intimate communion, as, for instance, sleeping or constantly living in the same room, to render the miasm effective."

Notwithstanding the discovery of the tubercle bacillus and the demonstration of its infective power, the hesitating and modified opinion expressed by Dr. Good in 1825 is, I believe, the opinion of most physicians in this country at the present time. Some bacteriologists and pathologists are inclined to go further than the facts seem to warrant, and to magnify the importance of the seed at the expense of the soil. Some pathologists have even cast doubt on the old doctrine of heredity, and on the important influences of bad sanitary surroundings in fitting the tissues to form a proper soil for the growth of the seed ; with them the fact of contagion overshadows all other considerations. The practical physician in his daily work does not see much evidence of immediate contagion from patient to patient. Many physicians of great experience do not believe that, apart from the influence of heredity and bad sanitary surroundings, tubercular diseases can propagate themselves. From a clinical point of view, the case was summed up a few years ago by the late Dr. Wilson Fox, an eminent authority on such matters :—"There are," he says, "few writers who have not admitted the possibility of some contagion, but I venture to think that the evidence as it stands shows that even if this possibility has an authentic foundation, the extent and degree to which contagion ordinarily extends is singularly small." If, he says, tuberculosis depends exclusively on the effect of bacilli introduced into the body, these may owe their power of germination in certain tissues to the weakening of the latter by disease or otherwise.

On account of this conflict in opinion, in the year 1883 a Committee of the British Medical Association sent a circular to the medical practitioners of Great Britain, asking them whether in their practice they had observed cases in which pulmonary phthisis appeared to be communicated from one person to another. The Committee received 1,078 returns, of which only 261 were in the affirmative. I have read over all the affirmative replies, with the result that, while in about one-half of the answers the details given are not sufficiently detailed to permit me to form an opinion as to the value of the evidence, some of them, however, are sufficiently detailed to enable me to say that they are quite worthless as evidence of contagion. I shall read a few cases to illustrate this class of replies (Cases 53,\* 166, 121, 134, 148).

But there are 130 replies in which sufficient detail is given to enable me to say that there is a great probability that direct contagion did take place. And what strikes me very forcibly in these affirmative evidences is the frequency with which the writer draws attention to the fact that the patients lived in most insanitary surroundings (see Cases 70, 87, 168, 169, 172, 191 †). A large proportion of these were cases of the disease being communicated from husband to wife. There are given 119 cases of wife infection from a deceased husband, and 69 cases of wife to husband. It is impossible to write on this subject without referring to the very extraordinary experience of Dr. Weber, of London, in this matter of wife infection. He details nine cases of presumably phthisical husbands who communicated the disease to more than one wife. Twenty-one young and healthy

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\* *Case 53.*—In 1877 I attended a young man, aged 23, for phthisis; he died 25th May, 1877. His wife, a strong healthy girl of about 20, without any previous family history, as far as I could ascertain, of phthisis, *commenced to be ill in the early part of 1880*, and died of acute phthisis on 10th March, 1880. The house they lived in was very small, ill ventilated, and in a close, poor neighbourhood. Note that in this case two and a half years elapsed between the death of the husband and the commencement of the wife's illness, making it quite certain that she was not infected by him.

† *Case 191.*—Some years ago, the wife of an officer left Calcutta for Southampton in a sailing vessel with her husband. She stated herself to have been in perfect health when she stepped on board. Her husband was in an advanced stage of consumption, and died at sea. The voyage was stormy, the hatches down, the cabin hot and close. I saw her three days after her arrival at Southampton, with both lungs stuffed with tubercles. She was an only child, and had no hereditary predisposition. In this case the evidence is very conclusive of infection from the husband.

women married these nine men, and of these 21 unfortunates 19 died of phthisis. One man was supposed to be responsible for having killed four wives, another three, and so on. The singular thing about these cases is that the husband was supposed to be cured before he married, and one would think that a man who could survive four wives, as in the first case recorded by Dr. Weber, and show no breakdown in his health at the end of it all, must really have been pretty well. This, in fact, appears to have been the view taken of this extraordinary experience by Drs. Addison and Hughes, of Guy's Hospital, who were called in consultation on the illness of the third and fourth wives of this unfortunate man. They hesitated about accepting Dr. Weber's view of the case, as the husband might be regarded as cured. This controversy has led me to look into my own experience with regard to contagion in phthisis.

With regard to phthisis in husband and wife, I have notes of seventeen cases among my own patients which resulted in death. In addition to these I have attended numerous cases of persons who either recovered or passed out of my observation, but I have not on any occasion known of the disease being communicated to the healthy partner; and in nearly all these cases the diseased and the healthy slept together for months or years in the same bed. The wife is more likely to be infected from a phthisical husband. I shall, by way of illustrating my experience, narrate six cases in which the husband died of the disease, and in which, with one exception, the wife slept with the dying husband up till within a day or two of his death. In the exceptional case, the wife slept in the same room in another bed, and nursed her husband until the day of his death.

*Case 1.* 1870.—Mr. N., master builder, æt. 30, suffering from phthisis, married a healthy young lady, æt. 24; went to Bournemouth immediately after marriage, and died there in seven months after; wife slept with him and nursed him, and remains alive and unaffected.

*Case 2.* 1872.—Mr. S., commission agent, æt. 38, died 29th September, 1872—ill two years. His wife, æt. 41, slept with him in the early stages of his illness, not afterwards, but nursed him till the time of his death. She was in the room with him night and day for the last three months of his life. Seven years after the death of her husband Mrs. S. began to cough, and now suffers from a chronic phthisis of the left lung.

*Case 3.* 1876.—Mr. M., master tailor, æt. 45, died after seven months' illness from phthisis; wife (æt. 37) and four daughters still alive and unaffected.

*Case 4.* 1877.—Mr. F., clerk, æt. 47, died from phthisis on 22nd September, after two years' illness; wife nursed him and slept with him till his death; wife and three children all unaffected.

*Case 5.* 1881.—Mr. W., commercial traveller, æt. 46, died from phthisis, 21st February, 1881. He had ailed for years; was confined to bed four months; wife and two children unaffected.

*Case 6.* 1888.—Mr. M., manufacturer, æt. 54, died in August, 1888, after seven years' chronic phthisis; wife and six children unaffected.

All these ladies are still alive, and, with the exception above stated, they remain healthy.

*Case 7.* I am at present attending a gentleman, æt. 35, who has been suffering from phthisis for at least five months. When I saw him first, a month ago, I found both of his lungs extensively diseased. I examined his sputum microscopically, and found numerous tubercle bacilli. No precaution was taken as to the disposal of this tubercular spit. Yet although this man's wife had slept in the same bed with him for four months, and two of his children had slept in a box-bed in the same apartment, the wife and the children remain up to the present time perfectly healthy.

I have in my note-book records of several families under my care in which one member after another died of this disease—for example, in one case a mother and five children, all of phthisis, in succession; in another case a mother and two children in succession; but the difficulty in the way of tracing these cases to direct contagion is the fact that, with the exception of the case of the first family mentioned, in which mother and daughter were ill together, and the mother appeared to take the disease from her daughter, none of the others were simultaneous cases. There was always an interval between the death of the one and the commencement of the illness of the other. When the interval was short, as in the case of a Miss B., where only a few weeks elapsed between the death of her sister in December and the commencement of her own illness in February, the probability of direct infection is increased. In my twenty-five years' experience I can only recall the cases of three families in which there

seemed to be a strong probability of direct infection, and in these cases the persons infected lived under very bad hygienic conditions; and there was, in addition, a probability of hereditary taint.

This leads me to consider what we know of the time which may elapse between the infection and the development of the tubercular lesion. Experiment has shown that in cases in which tubercular material, rubbed up with distilled water, was sprayed into the cages of animals used by Koch for experimental purposes, these animals, 217 in number, without a single exception, became tubercular within three or four weeks, and, when killed, showed numerous tubercles in their lungs and other organs.

In 1874 Demet and Zablonus, of Syra, in Greece, succeeded in inoculating a man of 55 with tuberculosis. The patient was dying of gangrene of the left foot, through obliteration of the femoral artery. Phthisical sputum was inserted into the upper part of the right leg, the lungs having been previously examined and pronounced healthy. Three weeks after the inoculation, signs of commencing induration of the right apex were detected, and seventeen days later the patient died of the gangrene. The *post-mortem* showed seventeen tubercles in the right apex, and a smaller number in the left apex, all evidently of recent formation. Under experimental conditions the incubation period may, therefore, be stated as from three to four weeks.

In ordinary practice, we must bear in mind that the dried spores in tubercular sputum may retain their vitality for six months; and, where no special care is taken with the sputum, there may be infection stored up in a house after the death of a patient for that length of time. We can thus understand a patient being infected during this six months' period when no disinfecting measures have been used. From these data we may conclude that any case which arises, after the lapse of eight months, in a house in which a phthisical person has died, has not arisen from infection derived from the previous case, but from some other source.

#### ARE THERE TUBERCLE BACILLI IN THE BREATH OF PHTHISICAL PATIENTS?

There is a difference of opinion among modern authorities on this important question. As Nägeli, Carmichael, and others have proved by experiment that even strong currents of air are unable to detach bacilli or their spores from moist surfaces, it is

*à priori* improbable that the tubercle bacillus or its pores can be carried by the air currents of the breath from the moist cavities of diseased lungs through the moist air passages. Nevertheless, Dr. Ransome, of Manchester, and Dr. Williams, of the Brompton Hospital, London, state that they have found tubercle bacilli in the breath of advanced cases of phthisis pulmonalis; while, on the other side, Cornet states that he has never been able to propagate this disease by the inoculation in susceptible animals of the condensed vapours from the breath of phthisical patients.

An examination of the experimental basis on which Drs. Ransome and Williams found their opinion seems to me to show that these observers did not take sufficient care to eliminate sources of fallacy in their experiments. I am satisfied that the bacilli found by Dr. Williams in the extraction shaft of the Brompton Hospital were much more likely to be derived from the spraying of the air of the ward with particles of sputum during the violent fits of coughing to which consumptive patients are liable, and to the drying of sputum on the clothing and on the floor of the ward, and its subsequent dissemination in the form of dust. There is no evidence whatever of its having been derived from the breath of the patients experimented on. The details of Dr. Ransome's experiments, as given in the 34th volume of the "*Proceedings of the Royal Society of London*," are quite insufficient to prove that precautions were taken to prevent the coughing of the patient, or the contamination of the air in the large glass globe into which the patient breathed with dust particles from the ward. Dr. Ransome states that in several cases of acute phthisis the search for the organism was unsuccessful, and that he only discovered the bacillus in two cases. As in the case of Dr. Williams' experiments, so in his cases the probabilities are that the bacilli were derived from particles either coughed out by the patient or disseminated in the air of the ward by dust particles from phthisical sputum.

In order to eliminate such sources of fallacy, I performed a series of six experiments in cases of advanced phthisis, which were under my care in the Victoria Infirmary, in the following manner :—

On the 5th of March last I examined the sputum of a young woman who had all the physical signs of tubercular disease of her right lung, with a cavity forming in the apex. I found,

on staining her sputum in the usual way with Gibbe's double stain, that it was crowded with tubercle bacilli. She was being treated in a side room in which there were no other phthisical patients. Her sputum was carefully collected in a spittoon, and she was prohibited from spitting on or into anything else. The room in which she lay was amply ventilated on the system of propulsion, warmed air being driven in through a shaft, the inlet of which was 5 feet above the level of the floor. The opening of the outlet shaft was at the floor level, so that any fine particles of sputum sprayed into the air in coughing would be carried out by the air currents at the floor level.

I smeared a glass slide with the sputum of a bronchitic patient which I found to be quite free from bacilli. I asked the phthisical patient to breathe upon the moist surface of this slide for a quarter of an hour every two hours during the day. This she did every day for a week. I cautioned her never to cough upon the slide, and each time, after breathing upon it, to place it, with the moistened side uppermost, in a small box with a lid, in which it was protected from dust. At the end of the week I stained this slide as stated, and examined it very carefully, with the result that I could not find on it a single tubercle bacillus. This experiment I repeated three times in the case of this patient, with a like result.

In three other cases of well advanced phthisis, with characteristic sputum in which the bacilli were demonstrated, I repeated this experiment with the same precautions, and with the same result.

First, on the theoretical grounds already stated; secondly, on the ground of the comparative rarity of the direct infection of healthy persons who are brought into close contact with phthisical patients, and who are constantly inhaling their breath; thirdly, on the ground of the negative results of Cornet's inoculation experiments; and, lastly, on the ground of the negative results of my own experiments just detailed, I am of opinion that neither tubercle bacilli nor their spores are ever found in the breath of consumptive patients.

This aspect of the question leads me to consider the defences of the healthy body against the invasion of the bacillus and its spores. Every one of us must at some time have eaten tubercular meat, drank tubercular milk, or breathed dust particles laden with tubercular bacilli; and yet, I suppose, most of us have

escaped tubercular disease. What prevented it? The most common avenue of entrance for this bacillus is through the lungs. Dried sputum of phthisical patients may be met with in every public vehicle, and in every public place where any large number of people assemble together. Some of it gets into dust, and occasionally we breathe it; but in a healthy state of the air passages, if this dust, by chance at an odd time, succeeds in passing through the moist passages of the nose and throat into the bronchial tubes, it is caught there by the mucus lining these passages, and, by the action of the cilia, carried up again and expelled. These epithelial cilia constitute the first line of defence. If, however, the mucous membrane is denuded of its cilia by repeated catarrhal attacks, such as most of us experience at times, so that the bacilli gain an avenue of entrance, the battle is not yet lost—we have an army of reserve to defend us. It takes three weeks for the enemy to propagate and increase his forces, and, in the meantime, he is vigorously attacked by the white corpuscles of the blood, which crowd to the point of invasion, and literally eat up the enemy and digest him. It is probably only when the breaches in first line of defence are numerous and extensive; when the enemy is in great force, and his forces are constantly replenished; and, further, when our second line of defence, the leucocytes, is weakened by the breathing of a bad atmosphere, and other insanitary conditions, that the bacillus can gain the victory. Such a combination of circumstances, fortunately for the human race, is only found at rare intervals in the average man or woman; and so we continue to defy the bacillus as long as we can continue to maintain our forces in good fighting condition.

In the case of the ingestion of tubercular food, similar protective forces are at work. We have no epithelial cilia lining the mucous membrane of the stomach or intestines to expel the intruders, but we have the daily action of the bowels to carry them down. If we keep our bowels in daily action, our mucous membranes healthy, and our leucocytes in good fighting trim, we do not need to fear the bacillus. Even if the enemy should effect a temporary success, there is still the hope that, by judicious treatment—a result of good feeding, fresh air, and healthy occupation—and without the use of drugs of any kind, our leucocytes may rally and destroy the enemy before he has time to increase his forces to any serious extent.

To sum up the whole matter from this point of view—I believe that tubercular diseases are always derived, directly or indirectly, from pre-existing cases by contagious particles ; but I am quite certain that in the genesis of the majority of the cases the contagium has been enabled to take effect only by the pre-existence of bad hygienic conditions, which have prepared and manured the tissues of the victim for the growth of the organism. In this way we may harmonise the views of the ultra-contagionists with the opinions of those experienced physicians who deny that contagion is the prime factor in the spread of these diseases. I hold that the facts which I have adduced establish the paradox that, while it is quite certain that phthisis pulmonalis is always got by contagion, yet the fact of contagion is of only secondary importance in the consideration of the preventive measures to be adopted to prevent its dissemination.

The most important causes which predispose man and other animals to offer a fitting soil for the growth of the tubercle bacillus are as follow:—

1. Heredity.
2. Breathing of impure air.
  - (a) From insufficient air-space, defective lighting, and bad ventilation in houses and workshops.
  - (b) Contamination of the air of workshops with dust particles and metallic vapours in certain trades.
  - (c) Contamination of the air of houses and workshops with sewage gases.

1. *With regard to Heredity.*—With our present knowledge, we do not believe that tubercle bacilli or their spores are directly transmitted to the offspring, either by the father or by the mother. But certain peculiarities of constitution are certainly transmitted, which favour the lodgment of dust particles in the respiratory passages, and favour the chances of growth for such tubercle germs as these dust particles may contain. Imperfect development of the chest and a tendency to catarrhal affections of the respiratory passages are the most usual transmitted predisposing causes. We may also reasonably suppose that, in consumptive families, the leucocytes have less than the normal amount of vitality and fighting power, so that they are less able to cope with and destroy the invading bacilli than the vigorous and aggressive

leucocytes of non-consumptive families. I fear we shall never completely remove the inherited predisposing causes, but we can do much to modify them by attention to—(1) the proper use of calisthenics in childhood to develop the imperfect lungs; (2) by attention to the purity and abundance of the air in sleeping apartments. I strongly urge the parents in such families to cultivate the habit of sleeping with the upper sash of the bedroom window an inch down at the top, and the chimney left quite free from obstruction, so that there may be a free circulation of the pure and wholesome *night air*, which, in a city, is the purest air we can breathe. In feeding their children, the greatest care should be taken to boil all the milk which they use, and to accustom them to overdone rather than underdone meat. There is no doubt that unboiled milk and insufficiently cooked flesh are a serious danger to such persons. Children should also be enjoined to eat fat, which, as a rule, they object to. When they reach maturer years they should choose an occupation which leads them into the open air, and, if it is possible, they should avoid large towns, and endeavour to live in an isolated, sparsely populated district, where they will be less likely to come into frequent contact with men and animals suffering from tuberculosis. If we could isolate consumptive families in such a way that they would never breathe tubercular dust or eat tubercular food, they would be absolutely safe from the danger of tubercular disease.

2. *The breathing of impure air as a result of insufficient air-space and of insufficient removal of the products of respiration, transpiration, and combustion.*—The evidence that, on the large scale, this is the chief cause predisposing to tubercular disease is most abundant. A consideration of the facts on record has led me to form the opinion that the contagiousness or the non-contagiousness of pulmonary consumption varies in direct ratio to the amount of air-space and of free ventilation of air in the dwellings of the people. Taking the factor of cubic space alone, Dr. Guy, many years ago, calculated that among 10,000 letterpress printers, in a work-room with air-space amounting to 800 cubic feet per man, 400 would die annually from consumption; while, of 10,000 men working in rooms with an air-space of less than 500 cubic feet per man, 1,200 would die in the same time—that is to say, as 3 to 1. The experience of barracks and prisons tells the same story. Previous to the inquiry of the Army Sanitary Commission in 1858, the cubic space per soldier in the barracks

of the Foot Guards was 331 cubic feet, and the mortality from phthisis was 13·8 per 1,000. In the Horse Guards, on the other hand, with a space per man of 572 cubic feet, the mortality from phthisis was 7·3 per 1,000. Since 1861 the cubic space has been increased in English barracks to 600 cubic feet per soldier, and ventilation and sanitary arrangements have been better attended to, with the result that the mortality from phthisis has been reduced to less than 3 per 1,000. As an example of the effects of bad ventilation in prisons, Dr. Parkes, in his “*Practical Hygiene*,” adduces the case of the Prison of Leopoldstadt, at Vienna, which was very badly ventilated, and in which the mortality was 51·4 per 1,000 from phthisis; whereas, in the comparatively well-ventilated House of Correction, in the same city, the mortality from phthisis was only 7·9 per 1,000.

The case of the town of Kilmarnock illustrates remarkably well the improvement in the death-rate from phthisis which may result from a reconstruction of the old and insanitary houses of the poor. I quote from a letter on this subject, which I recently received from Dr. J. C. M’Vail, who was until recently the medical officer of health for that town:—“1. In 1861-70, Kilmarnock had the highest death-rate in Scotland, in either town or rural districts, from consumption. The ‘actual’ rate per million persons living was 3,881. What Dr. Robertson called the ‘adjusted’ rate was 3,346, but by both standards Kilmarnock had the worst rate of any population in the country. I enclose a cutting giving some of the ‘adjusted’ rates. In the five years, 1885-89 (the figures for 1890 being not yet available), the following were the *actual* death-rates per million—comparable, that is to say, with the 3,881 rate already given:—

1885	1886	1887	1888	1889
2,100	2,420	2,250	2,020	2,320

You will see what an enormous reduction is here. 2. It is not possible to give statistical data regarding the improved house accommodation. The improvement consists in the building of many new streets of workmen’s houses of a good modern type—of increased cubic capacity; with walls lathed as well as plastered; with wooden floors ventilated underneath; with, in most cases, damp-proof courses in the walls; with slated roofs, and so on. These have taken the place of old, damp, thatched houses, with floors level with or below the ground, and often paved with brick

or with a rough kind of concrete, or merely with clay ; with walls not lathed ; without ventilation underneath the floors ; with many of the windows fixed ; with low ceilings, &c. A main cause of the great alteration was a local Improvement Act, which gave the Corporation extensive powers of sweeping away old streets and laying out new ones. The town spent a lot of money over the business, but it has had a magnificent return in its lowered death-rate from phthisis."

The theory that tuberculosis is highly contagious under the insanitary conditions just indicated, and non-contagious under proper hygienic conditions, explains many of the conflicting statements placed on record by trustworthy observers. For instance, the alarming mortality from phthisis among the Catholic nursing orders in Prussia, as shown by Cornet, who ascertained that out of 2,099 deaths from all causes among the members of these orders, phthisis was responsible for 1,320. I have no doubt that the reason for this alarming mortality is to be found in the fact that these devoted Catholic nurses spent their lives in nursing in the insanitary houses of the poor, where they were exposed to all the conditions which render phthisis an infectious disease. On the other hand, in the well-ventilated consumption hospitals of Brompton and Victoria Park, where the hygienic conditions were well attended to, the nurses are proved to have had almost complete immunity from tubercular disease. Out of 181 clinical assistants who have resided in these two hospitals only one has been known to become affected by phthisis during the period of residence ; and of 356 nurses, some of whom have spent years in nursing consumptive patients, there is only one doubtful case on record of what looked like infection. On carrying the inquiry further, it is found that the proportion of these hospital attendants who became affected with phthisis after leaving these hospitals was also singularly small—in all, three clinical assistants and four nurses. This theory is equally successful when applied to the statistics of Williams, Copland, Cotton, Fuller, and others. With regard to the question of direct heredity, where the observations were made in private practice among the better classes living in good sanitary houses, the percentage was small—in Dr. Williams' observations, 12 per cent. ; whereas in Drs. Cotton and Fuller's observations on hospital patients the percentages were more than double (24·1 and 25·7). In the latter case the insanitary houses from which the hospital patients

came made the difference. Similar observations apply to the lower animals. Tuberculosis increases among cattle in direct proportion to the extent to which they are confined in sheds and byres. Herds of bullocks fed chiefly in the open air are very slightly affected, and in the case of American cattle, which are never placed indoors for any length of time, tuberculosis is almost unknown. It reaches its highest percentage in the case of milk cows, chiefly because of the confinement of these animals in overcrowded and badly-ventilated byres. In considering the question of what can be done by the authorities, imperial and local, I shall endeavour to confine myself, not to Utopian or ideal enactments, but to what is practicable. First, I am of opinion that we cannot hope to deal effectively with tubercular diseases by methods of isolation and disinfection in the case of man, or of slaughter and destruction in the case of cattle. Take Glasgow alone. In round numbers we have had, taking the average of the last ten years, 2,000 deaths annually from tubercular diseases, and of these, 1,500 deaths are from phthisis pulmonalis. If my calculation of 10 patients for every death is approximately correct, there are at least 15,000 patients more or less dangerous, from the expectoration which they scatter abroad, a large number of whom are able to go about their business, and are quite ignorant of the nature of their disease. Under these circumstances they repudiate any constraint upon their freedom, and the very suggestion of their suffering from such a disease would be indignantly denied. In incipient cases it is sometimes impossible for an experienced medical expert to be certain of the presence of tubercle; and even when he is quite certain of it, he often finds it necessary carefully to avoid the name of consumption, as this would in many cases greatly alarm the patient, and prejudice his chances of recovery. In many cases he would look upon such an announcement as signing his death warrant. Then, again, it is extremely difficult to say, in a chronic case of phthisis, when the patient is absolutely safe. The tubercle bacilli may be absent from the sputum for weeks or months, and still the disease may be smouldering in the lung, and occasionally in an infective stage.

Again, these people are suffering from a disease whose duration is measured, not by days or weeks, as in the zymotic fevers which we are accustomed to isolate, but by years. Even if it were practicable to get the tubercular million of the popula-

tion of Great Britain to submit to be treated as the lepers of old were dealt with, the expense would be so enormous as to be quite prohibitive. In the cases of the workers in crowded workshops, and the dwellers in single apartments and rooms and kitchens, the sanitary officials might do great good by looking into the ventilation and sanitary condition of these places, and advising the people as to the disposal of the phthisical sputum, which we have seen to be the most dangerous material. Every death from phthisis should be notified to the medical officer of health, and, in view of the persistent infectivity of the spores of the tubercle bacillus, in such cases the sanitary officers should disinfect the house and clothing of the deceased, and inquire into the sanitary condition of his dwelling, and of the workshop in which he may have contracted the disease. It would also be possible for local authorities to enact that every room in a lodging-house or hotel which had been occupied by a consumptive patient should be thoroughly cleansed and disinfected to the satisfaction of the sanitary authority. The imperial authority ought to enact that on board ship consumptive patients should have separate sleeping accommodation. This is a most important matter, as the conditions on board ship, in respect to insufficient cubic space and bad ventilation, are the most favourable for the spread of the tubercle bacillus.

With regard to hospital accommodation for such cases, I think, on humanitarian grounds, it would be a great boon to the unfortunates who are refused admittance to our infirmaries, on the ground of their hopeless condition, if they were provided with a home, like the home for incurables, where they might end their days in peace and comfort. This would also tend to diminish the risk of infection which undoubtedly exists in the small, badly ventilated, and crowded houses of the poor. In the curable stages of the disease, I do not think there is any danger in treating cases of consumption in a well-ventilated general hospital, if proper care is taken to prevent the patients from spitting about the wards.

With regard to the question of what we can do with tubercular cattle, I think sanitary improvement in the byres and hygienic treatment of the cows are the only preventive measures which are likely to be effective. I do not think that we shall succeed in doing much good in limiting the spread of these diseases if we restrict our action to the slaughter of diseased animals

and the destruction of diseased meat. In the first place, the veterinary surgeons tell us they are not able to recognise the presence of tuberculosis in the living animal except in the later stages of the disease, and even then not with certainty, so that slaughtering is of little use as a preventive measure. In the second place, meat inspection, as at present carried on in Glasgow and elsewhere, is, as far as tuberculosis is concerned, most inefficient, and very little better than a pretence. Instead of being a protection to the public, it gives a false feeling of security, while, as a matter of fact, the danger is almost as great as if there was no inspection whatever. This is apparent when we consider that, while the amount of tubercular disease in cattle ranges from 5 to 20 per cent., the number of cattle condemned for tuberculosis in Glasgow is less than 1 per cent. In other parts of the country the meat inspectors are equally incompetent to protect us from tubercular meat and tubercular milk. Under these circumstances, no milk should be used until it has been boiled, and no flesh should be eaten until it has been thoroughly cooked to the centre. The cultivation of these habits will do more to protect us from this source of infection than any number of the most careful and competent inspectors can ever do.

The facts which have been adduced to-night seem to me to prove conclusively that, on the large scale, the greatest good can be got by the improvement of the houses and workshops of the people. What has been done in the prisons, what has been done in the army, and what has been done in our other public institutions, may be done in the crowded centres of population in Glasgow, if the authorities persevere in the policy of improving the house accommodation, and attending diligently to the other sanitary requirements of the people. As leprosy and typhus fever were abolished, not by leper hospitals and enforced isolation, but by improvement in the general sanitary-condition of the people, so may the tubercle bacillus be deprived of the conditions which are necessary for its successful dissemination. As a result of the renovation of the old and insanitary houses of the poor, the mortality from tubercular diseases has already been greatly diminished in this country; and by the general adoption of sufficient cubic space and proper ventilating appliances in the dwellings of men and animals, the ultimate extinction of tuberculosis may become a possible achievement.

XVI.—*Fogs: A Review of our present position regarding them.*

By W. ERNEST F. THOMSON, M.A., M.B.

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[Read before the Society, 3rd February, 1892.]

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WHEN the President of the Sanitary Section of this Society asked me to read a paper on the subject of Fogs, I was quite under the impression that something could be done and should be done to lower the percentage of foggy days in large cities to the same percentage as in the country. But since, for the purpose of this paper, I have gone more closely into the subject, I am bound to confess that our position, as regards city fogs, has been rendered a very pitiable one by the brilliant researches of Mr. John Aitken, F.R.S., to whose experiments I shall refer at considerable length.

But, before going into the question of city fogs, let us take a general survey of the whole class of atmospheric phenomena included under the common term fog.

*What is Fog?*—It is water in a state of minute sub-division, the watery particles being in intimate contact with particles of dust. Let us, in the meantime, ignore the question of the dust particles as a necessary constituent. I shall refer to that later on. Fog is, in plain language, low-lying cloud—a condition intermediate between rain on the one hand, and a clear, non-saturated atmosphere on the other.

Scott, in his “Elementary Meteorology,” says:—“The greatest amount of the water which passes into the atmosphere by evaporation is restored to the earth in the form of rain, snow, or hail. But, before the moisture takes the form of drops of appreciable size, it passes through the intermediate condition of visible fog, mist, or cloud.”

How is fog produced? Speaking generally, it is caused by one of two conditions—

1. By a lowering of the temperature of a body of air already holding its maximum quantity of water vapour for that temperature.

2. By a raising of the amount of vapour to be absorbed by that body of air, beyond the maximum possible at the prevailing temperature.

To make this clearer, let me remind you that a given volume of air is capable of containing, as a gas, an amount of water which varies with the temperature. The higher the temperature the greater is the vapour-holding capacity, and *vice versa*; so that, if the air be saturated with moisture in the gaseous form at 60° F., condensation of some of its moisture will take place, and visible mist will result when the temperature is reduced below that point. So also, if the temperature remain the same, mist will appear when a surface of warm water is brought in contact with the air; for the warm water gives off vapour, and, as the saturated air cannot contain any more, the invisible vapour assumes the visible liquid condition.

Let us apply this knowledge to the explanation of natural phenomena. In the middle of summer there is not often much fog. In the autumn and winter fogs are prevalent. How are we to explain this difference? In summer there is not nearly the same variation of temperature in the different parts of the twenty-four hours as in winter. The warm summer air can hold as vapour a large quantity of water without becoming saturated, and since the temperature never becomes very low at any time in the twenty-four hours, there is but little tendency to condensation. But when the weather becomes colder, and the variations in temperature more marked, the warm mid-day air is still holding a large amount of vapour. But the sun sets early, the air becomes cold, and being unable to contain so much vapour at its now reduced temperature, expels, as it were, its surplus into the liquid state again. In the autumn, the rising sun tends to dissipate this morning mist by again raising the temperature; but in winter, as we all know, he very frequently fails.

Again, when two masses of air, the one much cooler than the other, become mixed, it may happen that the resulting temperature is insufficiently high to retain as vapour the total moisture of the two masses, and part of it condenses into visible liquid, the minute particles of which tend to carry down with them other foreign particles floating in the air.

If we study the atmospheric conditions in such a city as Glasgow, we shall find that they are eminently favourable to the occurrence of fog. The river bed is warm partly due, no doubt,

to the constant flow of warm water into it from manufactories. The air is warm, due to the great amount of heat given off by fires of all sorts. It is holding a large quantity of vapour, and a high percentage of soot; for I am assuming that the weather is calm. Suppose, now, a gentle but cold breeze springs up. The cold air mixes with the warm saturated air, and the resulting temperature is lower than that which prevailed before. Condensation takes place, and we are wrapped, perhaps for days, in a pea-soup fog. You will also often notice, under these circumstances, that the fog tends to be exceptionally dense over the Clyde and the Kelvin; for when a warm current of water has lying over it, a cold saturated mass of air, the water gives off vapour in greater quantity than the air at its low temperature can contain, and the surplus condenses as fog.

The fogs over the Banks of Newfoundland are formed in a similar manner; but in this case a warm, saturated current of air passing over a cold ocean current, becomes chilled, so that some of its moisture must condense into the visible liquid form. We shall see later on that the salt particles in the air must have much to do with the extreme density of these fogs.

Then there are "radiation" fogs, formed towards evening in the country, and caused by a cold mass of air rolling down a slope and mixing with a saturated, warmer mass of air next the ground. They disappear after sunrise, when the air becomes warmer and again absorbs the moisture.

The sea fogs, so prevalent on the East Coast, are caused by a cold wind from the east mixing with the warm damp atmosphere over the water. When the fog meets the drier air over the land the moisture is again taken up, so that this variety does not extend much beyond the coast line.

I shall refer presently to the important variety known as "dry" fog. (See "References," p. 13.)

Having now taken a glance at fogs in general, and seen how, although they occur under apparently different circumstances, the cause is yet the same in all; we must turn our attention more particularly to those which occur in cities; and it is in this connection that I shall bring in Mr. Aitken's results, showing the close relationship between dust particles and the condensation of water vapour. But before attacking this question it may be interesting to notice with what an old story we are dealing.

It is many centuries since London smoke was first recognised as a distinct inconvenience, and in the year 1661 it seems to have been pretty bad, judging by a most interesting paper by John Evelyn, published in that year (2). It is a petition to the king in favour of taking drastic measures to subdue the smoke nuisance; and it seems a most extraordinary and unaccountable fact that now, in 1892, more than two hundred and forty years later, matters are infinitely worse, instead of better, than they were.

Evelyn refers to the fact that the "smutty atoms" are destroying the orchards about the Strand and Barbican, and compares the City of London to "the face of Mount Etna, the Court of Vulcan, Stromboli, or the Suburbs of Hell."

He tells us how, when Newcastle was besieged—"The divers gardens and orchards planted even in the very heart of London (as in particular my Lord Marquess of Hertford's in the Strand, my Lord Bridgewater's, and some others about Barbican), were observed to bear such plentiful and infinite quantities of fruits as they never produced the like either before or since." He imputes this year of plenty to the absence from London of Newcastle coal.

Then, again, in reference to the increased death-rate from smoke, he remarks:—"But how frequently do we hear men say—'He went up to London and took a great cold,' . . . 'which he could never afterwards claw off again.'" He scoffs at the opinion of some of the physicians of the day, that smoke is rather a preservative against infection, sarcastically remarking—"If any shall find themselves agreev'd and think good to contend, I shall easily allow him as much smoake as he desires, and much good may it do him." And in another place he humorously says—"How it sticks to the hands, faces, and linen of our fair ladies; the prodigious waste of almond power for the one; soap and wearing out of the other do sufficiently manifest." After all, his proposed remedy is that manufacturers should "move on," as it were, out of town; an arrangement which could not even be considered so long ago as 1661.

Let us now briefly consider what it is that we throw out into the air from our fires. Some of these substances we shall find to be avoidable, and some unavoidable, accompaniments of combustion. In Parke's "*Manual of Hygiene*" the products of combustion of average quality coal are given as follows:—Carbon, *i.e.*, soot, carbonic acid, carbonic oxide, sulphur, sulphurous and sulphuric acids, carbon bisulphide, ammonium sulphide or carbonate,

sulphuretted hydrogen, and water. Note what a large amount of sulphur is here represented.

Mr. Fletcher, of Warrington, gives the following figures (3):—Every ton of coal contains—2,000 lbs. of carbon; 110 lbs. of hydrogen; 33 lbs. of sulphur. Giving, as the result of its combustion, 6,700 lbs. of carbonic acid; some carbonic oxide; 1,000 lbs. of water; 112 lbs. of strong sulphuric acid. The sulphuric acid arises by the oxidation of sulphurous anhydride.

You will all have noticed the evil smell in the air when the wind is easterly, and blows from the St. Rollox quarter. The smell is, I believe, chiefly due to the escape of sulphurous gases from the chemical works. But it is not so much the gases from works that concern us, as those from dwelling-houses; and although these are, perhaps, not so concentrated as those from the chemical works, they are far more difficult to deal with.

If we could get fuel without sulphur, and use "perfect combustion" grates, we should get rid of a powerful element in the production of our city fogs, for, as I shall presently point out, Mr. Aitken has proved that sulphurous gases are powerful fog producers. We should not, it is true, get rid of the nuisance entirely; but consider how comparatively cheerful and country-like would be a Glasgow fog, without its characteristic "blacks" and its characteristic odour.

From what I have told you about the history of city fogs, and the composition of the products of combustion of ordinary coal, you will be led to think that some close connection exists between smoke and city fogs; that they stand related as cause and effect; and in order to show what is the relationship of the one to the other, I cannot do better than quote very fully from a paper by Mr. John Aitken, read a few years ago to the Royal Society of Edinburgh, on "Dust, Fogs, and Clouds" (4). I shall try and summarize his paper, and hope to be able to demonstrate to you his fundamental experiment upon which the others are based.

Aitken showed that a "free surface" is necessary for the condensation of vapour, for the freezing of water, and for the passage of water into vapour. Just now, the first only need occupy our time, namely, the passage of water from the gaseous to the liquid state. He found that if steam be passed into a glass receiver containing ordinary air (such a receiver I show you here), but closed so as to prevent the further ingress of dusty air, a thick fog will form which will gradually settle, as you see it settling

now in this receiver before you. But if steam be blown into another receiver, such as this other one, filled with air which has been filtered through cotton wool, no fog whatever will be seen. If, after the fog has settled in the first receiver, more steam be allowed to enter, fog will again result. After repeating this a few times the resulting fog becomes less dense and coarser grained; the first-formed fog having been very dense and fine grained. Finally, no fog will appear at all, but only a fine rain will be seen slowly falling to the bottom, and, if further purified, the air contains no dust, and not even rain will be seen.

Mr. Aitken's explanation of this experiment is that the dust particles of unpurified air act as "free surfaces" upon which the water vapour may condense. When the air is filtered there is no dust, and becomes supersaturated in the receiver without any condensation taking place. The moment, however, that more dusty air is allowed to enter freely, fog will result just as in the first case.

He draws the following conclusions from the experiments:—1. When water vapour condenses in the atmosphere it always does so on some solid nucleus.

2. The dust particles in the air form the nucleus on which it condenses.

3. If there were no dust there would be no fogs, clouds, or mists, and probably no rain.

"As we do not at present know anything about the temperature of condensation of vapour when there are no free surfaces, we cannot tell whether the vapour in a perfectly pure atmosphere would ever condense to form rain; but if it did, the rain would fall from a nearly cloudless sky.

"When the air got into the condition in which rain falls—that is, burdened with supersaturated vapour—it would convert everything on the surface of the earth into a condenser on which it would deposit itself. Every blade of grass and every branch of tree would drip with moisture deposited by the passing air; our dresses would become wet, and umbrellas useless; but our miseries would not end here. The insides of our houses would become wet; the walls and every object in the room would run with moisture."

But why does the condensing moisture sometimes form fog, and sometimes rain or mist? The conclusion derived from the experiments is, that when the dust particles are present in great quantities fog is formed; each particle only getting a small share of vapour.

When, however, the dust is not in such great quantity each particle gets a larger share of vapour, and, increasing in size and weight falls as rain or mist. So far the experiments have been concerned with ordinary atmospheric dust, but most careful experiments were also made upon the fog-producing powers of the products of combustion, into the details of which time will not permit of my entering; so that, although they are important, I must ask those of you who desire to go fully into the subject to refer to Mr. Aitken's paper. Briefly, however, Mr. Aitken found that if gas which has been proved by the steam test to be dustless, be burned in air which has in the same way been proved dustless, the products of combustion, when led away into a dustless receiver, give rise to fogging by the steam test; and, in order to make sure that the combustion really caused the fogging, the gas was turned off, and the circulation of filtered air kept up in the receivers, when, after a little while, the steam test produced no fog whatever. Condensation nuclei have, therefore, been produced by the combustion. But how? To use Mr. Aitken's own words—

“Is it really dust which is driven off by the heat from the surface of glass, from the brass and iron wires, and from the other substances? It is extremely probable that it really is an extremely fine form of solid matter which has been produced under these circumstances. Further, they have all been put to the test of the cotton wool filter, and all of them have been filtered out, and the air made non-cloud producing. If it was some gas or vapour which was produced by the heat, we see no reason why the cotton wool should have kept them so completely back.” Moreover, it was found by experiment that the products of combustion of a smoky flame and of the clear flame from a Bunsen burner were about equally bad as fog producers; so that, it appears, combustion in any form is a potent factor in the production of fog, under certain conditions of atmosphere and temperature.

There is a form of fog which I mentioned a little while ago—namely, “dry” fog—which is caused by the condensation of vapour in unsaturated air, owing to a chemical affinity between the dust particles and water. Such particles are, for instance, common salt, sulphite of ammonium, and sulphate of ammonium. The presence of the former in the air near the sea, and in great quantity, accounts for dry fogs in such localities and for the dense fogs over the Newfoundland Banks. The sulphite and sulphate of ammonium are formed by the union of the products of combus-

tion of sulphur with ammonia. These particles, in the form of very fine dust, have the power of determining the condensation of water vapour in unsaturated air. Now, our coals mostly contain a large amount of sulphur, so that, apart altogether from soot (which can be avoided), every fire we burn in our dwellings, to say nothing of manufactories and works, tends to help in the formation of fog in certain conditions of the atmosphere.

Let me just repeat, then, what Aitken's experiments show :—

1. Condensation of water from the gaseous state only takes place in the presence of "free surfaces."

2. These free surfaces are afforded by various forms of dust always present in the atmosphere.

3. Some of these dust particles have a chemical affinity for water, for instance, common salt and sulphite of ammonium.

4. These, having a chemical affinity for water, tend to produce condensation in unsaturated air.

5. The greater the quantity of dust the greater the tendency to form fog, and the less the quantity the greater the tendency to form mist or rain.

6. In towns the dust is in great amount ; it has (some of it at least) a chemical affinity for water, so that if the air be rather still and cold there is a great tendency to fog formation.

Very much has been said in the past about soot as the cause of fog, but I think these experiments have made it clear that the sulphur compounds rather than the soot are to blame. The "blacks" must act as condensation nuclei to some extent, but they fall owing to their weight, while the smaller sulphurous particles with their coating of water are infinitely more numerous, and being light, remain suspended in the air.

I would now make just a few remarks on the effects of fog on living organisms. It is a matter of fact that for years past it has gradually become more difficult to rear plants in large cities, and that this difficulty increases step by step with an increase in the percentage of foggy days. There are two reasons for this. Firstly, sulphuric acid is deposited on the leaves ; and secondly, they are deprived of sunlight. If one keeps plants, ferns for instance, over the winter in Glasgow, one notices how after a spell of fog they droop and appear to be dying ; but plunge the leaves in tepid water, or sponge them carefully, and a great change for the better will be observed. It is even possible to turn blue litmus paper red when it is brought in contact with the sponge which has

been used for the leaves, thus demonstrating the presence of the free acid.

Regarding human beings, it must be borne in mind that along with fog the weather is apt to be intensely cold, and cold weather means, even without fog, an increase in the death-rate, largely due to the deaths of old people in poor circumstances who cannot find means to keep themselves warm. Somehow I do not think that fog of itself is so destructive to human life as is sometimes supposed, although there can be no doubt that it does increase the number of deaths from diseases of the respiratory organs.

There are several ways in which foggy weather may be prejudicial to human life, apart from actual cold—

1. By the irritating action of the sulphur and soot on the respiratory passages.

2. By the withdrawal of light from our daily life, and corresponding mental depression.

3. Possibly by the poisonous effects of sewer emanations carried down from the ventilating shafts of sewers. These emanations have been said to cause "fog diarrhoea" (5).

4. By the substitution of carbonic acid for some of the oxygen. It is said that in still, foggy weather, the carbonic acid from the chimney tops falls owing to its high density, and mixes in undue proportion with the air next the ground.

I think, however, that it yet remains to be shown, how far preventible "pea-soup" fog, fog containing soot and sulphur, which are unnecessary products of combustion, is worse as regards the death-rate than it would be if freed from these constituents.

It must be remembered that fogs *will* occur in riverside cities more frequently than in the country, even supposing we burn good coal in good grates; and they will always be cold and frequently wet, and so tend to raise the death-rate. Moreover, the death-rate is increased by accidents. In the late fogs in London, a number of men fell into the river and could not be rescued. So, also, deaths on the railway are increased; people get run over in the street, and so on.

But the fact remains that for one reason or another, fogs do materially raise the death-rate, and nothing should deter us from doing all we can to abate the nuisance. Apart from injury to health, fog means loss of time and loss of money. Loss of money to railway companies, steamship owners, and merchants, from

waste of time. Loss of money to householders from waste of coal, and waste of gas for lighting. One is afraid to quote figures as to the annual loss to the nation ; but it must be very great indeed.

#### WHAT CAN BE DONE TO IMPROVE OUR ATMOSPHERE ?

If Mr. Aitken's experiments are conclusive, which they seem to be, the answer is that beyond freeing the fog of soot and sulphur, we can do very little until the power of electricity becomes great enough and cheap enough to fire our houses (and for all I know, even then we may not be free of it); for according to these experiments, combustion in any form increases the tendency of the atmosphere to become foggy. But enough of what we cannot do : what we can do, or could do if we chose, is to prevent the issue of foul smoke from our chimneys.

Leaving aside the heroic suggestion of John Evelyn, what proposals have been made ?—

1. It has been proposed to heat our houses and cook our food by steam, sent out like our gas from a central establishment, and sold by the cubic foot. All well and good if people in this country would submit to it as they do in America.

2. To burn gas alone as a heating agent. But it has been calculated by Mr. Fletcher (3) to be ten times as expensive for heavy continuous work as coal burnt in a good smoke-consuming grate. And further, experiment has shown that even a gas flame is a fog-producer.

3. It has been proposed to legislate in the matter by compelling the use of properly constructed grates, which will give off little or no soot, and anthracite or semi-anthracite coal instead of bituminous coal.

This is the question which so exercised the public mind ten years ago, and resulted in the drawing up of a bill by the Smoke Abatement Committee, of which the following are the chief proposals :—

- (1) To give to the Metropolitan Board of Works and the city authorities powers of supervision and control of the heating arrangements of all new buildings, including dwelling-houses, in order to insure the adoption of such heating systems as are best calculated to minimise the production of smoke.

- (2) To give to the city authorities and local bodies powers to create, subject to the approval of the Home Secretary, bye-laws for the restraint of smoke in their respective districts.
- (3) To extend the provisions of the Sanitary Act of 1866 to the suppression of the excessive emission of smoke from dwelling-houses.

This most excellent bill, which, had it become law, would have been distinctly a move in the right direction, was thrown out owing to the great opposition of the Property Defence Association.

4. Burning hydrogen has been suggested as a heating agent.

5. It has been suggested that all coal used should be subjected to partial distillation in the gas-works before being supplied to the householder. It has been contended that in this way the gas companies will profit without any loss to the householder. Figures are given which seem to be well worthy of attention (6).

6. The subject of mineral oils as heating agents seems to me to be worthy of greater attention.

There is little doubt, I think, that in the meantime all we can expect to do is to minimise the output of soot and of such gases as are accidental products of combustion; and the only way to do this seems to be the compulsory use of properly constructed grates, and of a certain kind of coal, in dwelling-houses; Government inspectors being appointed to enquire into the kind of grate in use in each room of each house; a fine being inflicted of so much per annum upon each grate not according to the regulation principle the landlord to have the responsibility.

We have legislation already for the proper stoking of manufactory fires and furnaces, the machinery of which only wants oiling. What we ought to have obtained ten years ago, and still are crying out for, is legislation upon house fires; and until we get it nothing whatever can be done to improve the existing state of matters.

To talk just now of electricity as a source of heat would be to wander into Utopia; but the time may come when our successors may rejoice in a City of Glasgow as free from smoke as Calcutta, with buildings no longer begrimed, but shining in the sun.

The conduction of smoke in flues to a central dépôt where the gases may be removed and utilised is, I fear, the dream of a theorist at which all sage practical engineers will shake their

waste of time  
coal, r  
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Philosophical Society of Glasgow.  
I have heard the value of our Glasgow smoke put down  
at £100,000 per annum, and if such an estimate were but  
approximately accurate, even the sage, practical men might brisk  
up and think about it.  
The conclusions then, to which I think we must come regarding  
such riverside cities as London and Glasgow, are:—

1. We can never be rid of fog. We shall always have more fog  
than smaller towns not situated on rivers, owing to the rivers and  
the climate.
2. We can reduce its unpleasantness, its inconvenience, and, to  
some extent, its danger to life.
3. We can do this by Act of Parliament only.

Lest you should be too hopeful, however, I will quote an article  
from the *British Medical Journal* of January 2nd, 1892:—

"It adds some poignancy to the sufferings which we all endure  
from smoky fogs that they are often coincident with brilliant sun-  
shine, a high barometer, and the perfection of calm, fine, wintry  
weather outside metropolitan limits and influences. Nothing,  
however, can stir the apathetic indifference and inactivity of  
Londoners in the matter of the smoke cloud of the metropolis.  
Nor will they, perhaps, be much moved by the intimation which  
is made by Mr. Ernest Hart, formerly chairman of the 'defunct'  
or 'suspended' Smoke Abatement Institute, that there is an early  
prospect of the increase of the smoke nuisance in London. The  
recent action of Parliament has been of a kind likely to be  
disastrous. The Home Office has, for several years—ever since the  
active intervention of the Smoke Abatement Institute—brought  
the powers of the law applicable to factories and industrial works  
of all sorts effectively into operation so effectively that it may be  
said that for the last few years London has been practically free  
of any smoke of industrial origin. Henceforth, however, this  
department of the Home Office, with its efficient staff of police,  
will be abolished, and the powers will be transferred to vestries  
who often number the largest smoke producers among them. We  
know what that means here and elsewhere. It is idle to repine at  
an evil which it is in our own hands largely to remedy, and which,  
on the contrary, we daily aggravate. The very moderate and  
reasonable Bill promoted by the Smoke Abatement Institute, after  
being considered and approved by a Select Committee of the  
House of Lords, failed to survive the opposition of Lord Wemyss

and his friends, although it was supported by the Duke of Westminster and other great landlords, and actively approved by many local authorities. What is now being done will plunge us all, year by year, in deeper and more sooty darkness. But, perhaps, the very excess of the evil may one day arouse a desperate resolve to make what is now nobody's business part of our civic duties. Meantime, Londoners choke and grope, and utter many cries of angry despair, but lift no hand to help themselves. The Institute has become suspended from want of funds; the Bill has been thrown out; the machinery of the Home Office for preventing industrial smoke has been abolished; and only feeble voices are raised in the darkness."

In conclusion, I must say that I am disappointed with this paper. When I undertook to work it up I was quite persuaded that plenty of good plans must have been proposed and got lost sight of; but although the number of papers in the scientific and daily journals is legion, almost every writer quotes from the others, and the whole subject is a mass of conflicting views. Undoubtedly, the most original, and at the same time the most depressing researches are those of Mr. Aitken, for they show that by nothing short of a radical alteration of our heating system can we hope to modify the fog nuisance, much less abolish it.

I have not, of course, anything like exhausted the subject, for I have tried to leave all side issues alone, but my want of originality has probably exhausted your patience. I believe there are some here to-night who have a much better right to hold opinions on the subject than I can possibly have, and to these I now leave it.

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#### REFERENCES.

- (1) For the subject of Fog in general see Chambers' "Encyclopædia" and the "Popular Encyclopædia" articles "Fog." Also — Scott's "Meteorology," Buchan's "Meteorology," and various papers in *British Medical Journal* and *Lancet* from 1880-1890.
- (2) "Fumifugium, or the inconvenience of the Aer and Smoake of London dissipated," John Evelyn, F.R.S., 1661. Reprinted 1772. This paper is in the volume of Evelyn's works, which may be seen in the Glasgow University Library.
- (3) *Lancet*, vol. ii., p. 1090.
- (4) *Transactions of Royal Society of Edinburgh*, vol. xxx.
- (5) *Lancet*, vol. i., 1882.
- (6) Scott Moncrieff in *Nature*, vol. xxiii.

## DISCUSSION.

THE PRESIDENT then invited discussion, remarking that they were anxious to have a free exchange of views regarding this very important subject.

Mr. F. J. ROWAN, C.E., in opening the discussion, said, that their present position as regarded fogs was, apparently, that they were able to produce them in very large quantity, and of very bad quality. The researches of Mr. Aitken, to which Dr. Thomson had referred, had shown that it was almost impossible for them to expect ever to be clear of fogs; and even with very much improved methods of combustion they could never hope to eliminate all sources of fog-producing material. Some of the methods that had been proposed were, no doubt, practical; but the whole subject, to his mind, really resolved itself into one of cost. It was quite easy, for instance, to use coal for manufacturing operations in such a way as to remove the principal fog-producing materials—that was to say, to remove the larger part of the solid hydrocarbons, or of the constituents which produced soot when coal was consumed, and also to remove the sulphurous-acid producing material; but it was a question of cost, and manufacturers were not at all disposed to go to the cost of any preliminary treating of their fuel so as to produce results which were merely for the benefit of their neighbours. In the case of household fires it had long ago been suggested by Dr. Carpenter, who did not deal with the use of fuel in manufacturing operations, that all domestic fires should be worked by means either of gas or of coke, the solid fuel to be used so that there should be no smoke produced; but, there, again, the question of cost came in, and other questions also arose, one of which Dr. Carpenter touched upon when he said that, to deny to the average human being the right or the opportunity of poking the fire, was to reduce him to practical idiocy. He supposed the absence of smoke would greatly reduce the density of fogs, but nowadays, nobody who knew anything about the subject spoke about smoke consumption. It was well known that this was physically impossible. Once smoke was produced, it could not be consumed, and, therefore, what they required were simply measures for preventing the formation of smoke. These, however, were well known. There was no mystery about them. It was well known how, in almost every kind of operation, combustion could be made practically perfect, and Mr. Aitken had shown them, as

Dr. Thomson's quotations proved, that that would remove a large part of the most offensive ingredients in fogs, although it would not prevent the formation of fogs altogether. Dr. Thomson's very lucid and interesting paper put the matter in a nutshell, but some exception might be taken to one or two statements; for instance, Mr. Fletcher's analysis of coal would not apply universally; and again, the effect of fogs on plants no doubt might be due, to a large extent, to the absence of sunlight, but the very remedy which Dr. Thomson himself proposed—namely, the washing of the leaves, showed that a great part of the effect was due to the deposition of carbon particles on the breathing apparatus of the plants. As to electrical heating, if it became practicable, it was not heating by combustion, so that, if such a method could be applied, there was no doubt that it would free the air to a great extent from dust. But, in the light of Mr. Aitken's researches on dust, it seemed that it was not merely the dust that was produced by combustion in cities to which attention must be directed, but dust produced in all sorts of ways. The city authorities no doubt did a good deal to keep down dust, but if they were alive to the part which was played in the production of fogs by dust particles of many kinds besides those produced by the combustion of fuel, he thought it was quite possible they might still further reduce the quantity of dust which was allowed to float in the air.

Dr. HUGH THOMSON was glad to see that there was great interest being taken in the production of fog, because, fogs such as they had in large towns, must be productive of much injury to health. He might read a little quotation which he made on "Vitriolic Fogs." It was taken from a report of a special committee that had made an investigation in Manchester on the subject; and it had appeared in the *British Medical Journal*, of 21st March, 1891. It was evident that the combustion of coal was the great cause of these fogs, and more particularly of the injurious fogs, containing sulphurous acid and hydrochloric acid. Then the question came up, how were they to diminish them? As had been stated, it must be not by consuming smoke, because smoke in reality itself was not consumable. It was only the unconsumed carbon which could be consumed, and rendered, of course, invisible thereby, so that they might suppose it was consumed. But the sulphuric and hydrochloric acid, and all other impurities remained just as they were, so that, to some extent, the unconsumed carbon might be considered a wholesome thing, because it showed them, at all

events, that there was smoke there, whereas, the other might kill them, and they would not know anything about it. It seemed to him the only true way that this matter could be met was, by introducing some entirely new system of heating and ventilating, instead of having the ordinary open fire. When the question of the abatement of smoke was made the subject of a bill before Parliament, he wrote a letter to *The Times* on the matter, but the Editor did not put it in (laughter), thinking, probably, that it was too far advanced for the time. (The speaker here read the letter.) When they considered how imperfect the ventilation of the houses of the working-classes was, they would see what advantage there would be in such modes of heating and ventilation as that. Here they had an abundance of air, and they also had a speedy renewal of air for all the purposes they required; but if they went into the houses of the working-classes, where, according to the official sanitary arrangements, 400 cubic feet was the space required for each adult individual living in this city, what a renewal of air was necessary to maintain the atmosphere in a proper respiratory condition! During the night, when the fires were off, ventilation in that way was lost, and as the window and doors were shut, the condition of the atmosphere was a totally different thing in the night from what it was during the day; whereas, with such an appliance as he suggested, they could go on ventilating during the night as well as through the day, and being entirely at their command they could have it or not as they wished. There was one thing about the production of fog that he would mention. He did not know that anyone had accounted for it, that was fog forming, say, on the top of a hill, forming what was called a "night-cap." He had observed the same phenomenon in Arran, where he had seen for a distance of about a mile or two from the land that a cloud hung over the island, and over a part of the water towards Ardrossan—about a mile or two miles—and beyond that the atmosphere was perfectly clear, and the sun shining; but, for these two miles towards the land the sun could not be seen, and unless it were some electrical power, he did not see how it could be produced.

Mr. GILBERT THOMSON, C.E., said that, with reference to dust particles, if they removed them out of the city to the same extent as they existed in the open country, it would, perhaps, remove fogs, but it would simply convert them into mists. For instance, on the hillsides they had mists which were in no way inferior to the

fogs in the city, except that they were a great deal better in point of cleanliness; so that the great point was to reduce this dirty fog to a state of tolerable cleanness, and that, Dr. Thomson had shown them, was quite practicable. And it was well known that in manufacturing processes it was quite possible—if not absolutely—to abolish smoke,—at all events to diminish it to a very small amount. It was, perhaps, a question of expense, but it was a matter of fact that the expense of the carrying out of the operations was to a very large extent compensated by the saving in fuel, because it was perfectly well known that this black smoke meant a great waste of fuel. The question of diminishing smoke from household fires was a very different matter. The very nature of it prevented them from having a smokeless fire. It came, however, to be very much a question of careful stoking. He had himself experimented sometimes in showing how, by careful stoking of an ordinary office fire, by keeping it well heated up, and putting on the coal in such a manner as to let off no black smoke, the thing was perfectly possible; but it took too much time to stoke with so much careful attention. In the letter which *The Times* was misguided enough not to insert, there certainly seemed to be indicated a cure for fogs; but then there came in the impracticability of the matter. There was no doubt the thing could be carried out, but could it possibly be done in the present state of public opinion, or in any state of public opinion which was reasonably probable within the next century. His strong opinion was that it would not be so. The question of abolishing smoke fires was closely connected with that of ventilation, as the open fire in, he supposed, 999 out of 1,000 cases, was practically the only means of ventilation which a room had; and the state of ventilation at present prevented them abolishing the smoke, as at the same time they would abolish ventilation. He thought there was more prospect of the matter being settled by the substitution of other methods of heating, such as that of gas, which had been already referred to. He was not an authority on the gas question, but he thought it could be made to have a very much smaller balance as regards proportional expenses against it. One thing connected with electric light was, that the gas companies would turn their attention more to distributing gas, which would be largely used for heating and cooking. They knew that a great deal of that was done already, and he believed that a great deal more would be done. Then as to legislation of an extremely

drastic kind, he very much feared that was not a thing to be expected, and one could readily imagine that the occupation of the inspectors of the houses suggested would not be an enviable one. In the present state of public opinion, he said again, it was out of the question ; and the insisting on a certain kind of coal being used to the exclusion of all others was also out of the question. They could not, he thought, look to anything in the way of drastic legislation for the diminution of the blackness of their fogs ; but he believed they might have some hope in that direction by introducing some other means of heating than the ordinary domestic coal fire.

Mr. W. Key, Tradeston Gas-Works, said that for the past few years, when dense black fogs prevailed, he had been occupied in doing what he could to lighten the atmosphere, and he came that evening to find out how these fogs were to be prevented. Recently, he might say, the "Clerk of the Weather" took advantage of him by bringing on a fog when his gasholders were very low, the result being that the city in his district had to be put on a half-supply. Consequently, there was an enormous outcry about bad gas, which, of course, was not so. It was want of gas. He, therefore, wished to ask the author of the paper that night if it was not possible—if science had not arrived at such a stage—that they could get a little warning, say, twenty-four hours, when this enemy of theirs was approaching. If that were so, gas managers would be able to give the gas that was necessary during the time the sun was obscured. Could it not be possible, by keeping a close record of the state of the moisture in the air, by taking note of the temperatures, and, perhaps, to join with that the barometer pressures and the fluctuations of the wind, to obtain some idea of the approach of a fog. Let them suppose a fog was coming to meet them in the street to-morrow, was it not possible to prognosticate this beforehand. Such a forecast would be most useful to the citizens generally, as well as to gas people. He thought that was one of the most important things regarding fog. He agreed with Dr. Hugh Thomson that something might be done to make our dwellings more habitable during foggy and disagreeable weather, and free from the abominable smoke and dirt that are so objectionable to eyes and nostrils. A friend of his (also of the name of Thomson) had told him of an idea he had to build a terrace of houses, say, to begin with, those of eight or nine apartments, with nine or ten in a row, and to work the whole system

of ventilating and warming by propulsion from the basement of one of them, and his calculation showed a considerable saving annually by fuel and otherwise. There would be less labour, and he would have no fireplaces in the houses, and the windows would only open for cleaning purposes. In this connection, buildings such as model lodging-houses required some new system of ventilation, and he thought that if the new art galleries which were to be erected were treated in some such manner as Dr. Thomson had indicated, it would have a valuable educative influence on the crowds who would go there in foggy weather to breathe the fresh air.

Mr. A. G. MOORE, C.E., remarked that Mr. Key had touched on the meteorological aspect of the question, and there was no doubt that certain conditions of the atmosphere were necessary to produce fogs. He thought Sir William Thomson used to say in his class-room that it was necessary there should be a stratum of highly rarefied and cold air at a certain height above the ground. This condensed the vapour in the air and prevented it from ascending, producing fog. The disagreeable accompaniments of fog in towns were due to the fact that the products of combustion of coal, and other impure gases, were kept down on the surface of the ground in the same way as the condensed vapour. He thought too much was blamed on so-called black smoke, which was unconsumed carbon, for polluting the atmosphere. There would be only a small proportion of unconsumed carbon in the products of combustion issuing from a chimney stalk. There was no doubt that in Glasgow they had a great deal of that kind of smoke. They had a great deal of coal burned in Glasgow. Within a radius of ten miles from the Exchange, there would probably be as much coal consumed as within a similar radius in London. Then the coal in the neighbourhood of Glasgow was of a very smoky nature. The figures given by Dr. Thomson must have referred to English coal, as there was about 45 per cent. of volatile matter in Glasgow coal, of which 10 per cent. was water. Now, that 10 per cent. of water all went to assist in the formation of smoke. The water had to be volatilised, and it cooled down the fire. He did not agree with Mr. Rowan that smoke could not be consumed after it was formed. He could give them an instance where smoke was consumed. In old-fashioned bee-hive coking-ovens, burned from the top, such as they might see at Port-Dundas, a great deal of smoke came out, but when this smoke was

led through flues to a chimney, there was absolutely no smoke visible at the top of the chimney. The smoke must have been formed inside of the oven, but burned in contact with the red-hot brick surface of the flues, with a supply of air. He did not think, therefore, that smoke, even after it was formed, was unconsumable; and all smoke-consuming apparatus were not such absurdities as they were apt to be characterised. The real difficulty in steam-raising was, that they had always got a comparatively cold surface near the fire, which tended to condense smoke from the burning hydrocarbons. This could be done away with by excess of firing capacity, and in the second place by using non-bituminous coals, and by gas-firing. Anyone who had seen anthracite burned knew that it did not smoke. This, however, did not do away with the products of combustion. With regard to electricity, the only practical way they could raise it was by burning coal, so that there was still the smoke difficulty. But, to come back to fogs, he did not think they had got over the difficulty with them, even when they had secured perfect combustion of fuel. They must find out some means of regulating the weather to do that. The only thing to do was to get some means of lessening the amount of deleterious matter put into the atmosphere by the combustion of fuel, and so take away some of the disagreeable effects of fog. There was another point in connection with steam raising which he would mention, which was, that if they consumed a less quantity of coal they would naturally produce less smoke, and the waste of smoke was nothing like the waste of fuel by badly-applied machinery. Most of the engines in use consumed about ten times as much coal as they ought to do, and it would be a much greater economy to compel users of machinery to construct their machinery to use a certain quantity of coal per horse-power, than by making them consume their smoke more thoroughly.

THE PRESIDENT said he should like to ascertain if fogs were becoming more prevalent, whether they were denser, blacker, or yellower than they were, say, forty years ago.

Mr. ALEXANDER SCOTT said he rose to mention one point that he thought had not come out so much that night as he had expected. There was no doubt whatever that, by proper means of consuming coal, they might largely diminish the quantity used; but looking to the theory of the formation of fogs from the dust particles, he did not think that any mere economy that could be realised in the

consumpt of coal would so much reduce the number of solid particles in the atmosphere as to avoid fogs in large cities like Glasgow. He wanted to draw attention to another aspect of the subject. He thought, if he remembered rightly, that every ton of coal consumed produced not much less than half-a-ton of aqueous vapour, which was thrown into the air. Now, on a still day, with that aqueous vapour thrown into the air over the city, it was perfectly obvious that it must saturate the products of combustion in the air, with the result that the products of combustion would very soon turn the balance, and if they could materially diminish the coal consumption, they would avoid reaching the saturation point, and to a great extent avoid, or at least diminish, the fog. His own impression was, so far as he could recollect, say, thirty years, that fogs were not seriously increasing, either in frequency or in density.

Mr. W. R. W. SMITH said that, in his opinion, fogs in Glasgow had very much increased in density, and very much deepened, during the past thirty years. When he was a lad they were a very moderate affair. It seemed to him they were very much indebted to Dr. Thomson for his paper. It had brought to the front one special point, namely, that of drastic legislation, in reference to this question. Without going into the details of the discussion, he might say they had fogs everywhere; indeed, it seemed they could not do without them, and when they came into an atmosphere filled with dust, they had a dense, black fog. Man was a dirty animal, and whatever he had to do he made dust and dirt, and he had no conscience whether or not it troubled his neighbour. As to drastic legislation, he considered it preferable to putting down gas-pipes for a double supply for cooking and heating, because that meant tearing up every stair and house in Glasgow. Did they think they could get quit of the fog any more than they could get quit of the "middens," without legislation? When they insisted on drains, and when they insisted on having their streets cleaned, they needed legislation also, and he simply said that they must place power in the hands of the authorities if they wanted to deal with the fogs also.

Mr. GILBERT THOMSON said he did not mean to convey the idea that they wanted double sets of gas-pipes.

Mr. GEORGE C. THOMSON, F.C.S., said that, as an engineer, he had listened with great pleasure to the paper. He thought if they wished they could have a clean fog by simply getting rid of the

sulphur that was in the coal. If they sent the sulphurous acid in the coal into the air, they would still have the biting fog which did damage to the plants, and also to the respiratory organs of individuals. In reference to the quantity of coal that was burned in that neighbourhood, he ascertained some two or three years ago, that it was somewhere about 9,000 tons of coal per day that were burned, and that one ton averaged one per cent. of sulphur, so that they might guess there was a pretty large amount of sulphur sent into the air. Therefore, if they could get rid of the sulphur in the coal, they would not have very much trouble in any other way, as, when the fuel burnt in a town was wood, a fog was much like that on the hillsides. It was quite as dense, but there was no difficulty in breathing or going about in the light. It had not the darkness of the present fogs.

The SECRETARY remarked, with reference to the question of the President as to the frequency of fogs within the last forty years or so, that he could affirm with the utmost confidence that the fogs had been less dense of late years than they were, as Mr. Scott had already told them, say, thirty years ago. He could remember one fog in that time, whose equal he had not seen in Glasgow in recent years. He did not say they were more frequent or less frequent, but certainly there was less density, or less blackness, than he had seen forty years ago.

Mr. W. P. BUCHAN (who had taken the chair owing to the President having had to leave), in closing the discussion said that it was a letter which Dr. Thomson had written to the *Glasgow Herald* on the subject of fogs, which had induced him to persuade that gentleman to come forward and give them his views on the subject that night. He was sorry they had not had some electrical engineers present that night to favour them with their views, but he would take the liberty to remark that, quite possibly, a better knowledge of electricity, and what it could do on the subject, might keep them from having fogs so bad as they had been. Dr. Thomson's experiment had been an interesting one, as it showed them how a smoky flame and a clear flame produced about the same amount of fog; and Mr. George Thomson seemed to corroborate that experiment, by his remarks about the evil effects of the sulphurous acid. That, he thought, raised the practical suggestion as to whether there could not be some way of bringing that large amount of sulphurous acid away without its getting into the atmosphere, and so preventing the smoke having so deleterious an

effect as it had. It was said that that was a sanitary subject, but they might work at it scientifically, and spend any amount of time and money, and all "end in smoke," because they could not, as individuals, pursue their investigations out fully, and thus bring about some rational and really practical way of preventing fogs being so bad as they were. Notwithstanding the fact that Glasgow had so many tall and smoky chimneys putting forth such vast volumes of smoke into the atmosphere of the city, the fogs here were not nearly so bad as those in London, where they had none of those smoky chimneys. Did not that show that it must be the sulphurous acid, and not the large stalks? Therefore, he thought the State ought to take up this matter and devote a sum of money specially to scientific men to work the solution of the question out for the benefit of the whole public. Many subjects might be worked out privately, but there were some questions that required so much time and money that they almost called for a millionaire to solve them. Therefore, he thought it was the duty of the State to step in to give money for experiments, for the purpose of finding out how to prevent evils such as this to the community. He asked them to give Dr. Thomson a hearty vote of thanks for his paper.

Dr. THOMSON, in acknowledging the vote, said there was not a doubt that the great point was the sulphurous acid. Mr. Aitken's experiment seemed definitely to show that sulphurous acid was a most extraordinary fog-compelling power, owing to the affinity of sulphuric acid for water. The sulphur in the coal was undoubtedly far the most important point to be got at. As to drastic legislation, he could only say that, perhaps, a bill on the subject might some day pass yet. Then, regarding meteorological prognostications, they all knew what they were like. He did not suppose forecasts would be any better as regarded fogs than they were as regarded weather in general. Then, as to the consumption of smoke, it was said smoke was non-consumable. Did our iron-works, for instance, not draw off the smoke of their furnaces, and raise steam with the products of combustion from their furnace to work their machinery for the hot-blast in the iron-works?

Mr. A. G. MOORE—It is gas, not smoke.

Dr. THOMSON—Well, it is a product of combustion.

Mr. MOORE—Smoke is unconsumed carbon.

Dr. THOMSON—That is putting a limited term to the smoke which I did not mean. Regarding "night-cap" fogs, these were

formed, he thought, by the passage of a current of warm, saturated air up the side of the hill, over the top of the hill, and down the other side; but when the hot, saturated air got high, it became cold, and the current as it passed over the hill-top, took on the form of fog, and a certain amount of water was precipitated upon it.

XVII.—*Memoir of the late Sir Andrew Ramsay, F.R.S., formerly Director-General of the Geological Survey of Great Britain and Ireland, and Honorary Member of the Philosophical Society.*  
By JOHN YOUNG, M.D., Professor of Geology in the University of Glasgow.

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[Read before the Society, 20th January, 1892.]

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SIR ANDREW CROMBIE RAMSAY was born in 1814 at Whitevale, a group of villas whose privacy was secured by an annual exhibition of posts and chains which barred promiscuous traffic. His father, William Ramsay, a native of Haddington, was a partner in the firm of Arthur, Turnbull, & Ramsay, manufacturers of pyroligneous acid, charcoal, and other chemical materials. The late James Young, of Kelly, used to speak of W. Ramsay as founder of the bichromate industry in Glasgow. His mother, one of the Edinburgh Crombies, was a woman of considerable intellectual energy, and of a most happy temperament. There were four children, William, a civil engineer, who will be remembered in this society as for many years its Treasurer; Eliza, who married Mr. Dymock, the Procurator-Fiscal in Edinburgh; Andrew, and John, who died early in the West Indies. Mr. Ramsay died in 1827, and in 1831 Mrs. Ramsay, having sold the Whitevale House to Robert Napier, afterwards of Shandon, went to live in Montrose Street, where she had Lyon Playfair as a boarder during part of his student days.

Andrew was of delicate health in childhood, and was sent to a school in Saltcoats for some time, thereafter to Dymock's School in Glasgow. About 1831 he entered business, but in a few years gave up what was uncongenial to him. He had made the acquaintance of Professor Nichol, perhaps through the reputation he had as a young man whose literary tastes made him editor of a manuscript journal, *Ramsay's Miscellany*, of which I understand there are copies still extant. In this were discussed, during the two or three years of its existence, social, scientific, and political questions, and no doubt the youthful editor threw as much spirit

into this enterprise as he had done into his leadership of the Whitevale boys against the "Low Camlachie keelies." On his retirement from business in 1840 he went to Arran to recruit his health, and there began systematically the studies which became the work of his life. In 1841 he joined the Geological Survey under Sir Henry de la Beche, and in 1845 was made Local Director for Great Britain. In 1847 he became Professor of Geology in University College, London, and in 1849 was elected F.R.S. In 1851 he resigned his University College Chair on assuming the corresponding position in the School of Mines, Jermyn Street. In 1852 he married a daughter of the Rev. James Williams, Llanfairynghornwy, near Holyhead, who (with a son and four daughters) survives him, after a wedded life of 40 years. Those who were fortunate enough to be admitted to the friendship of that house know what a home it was. The sympathy which rendered tolerable the early peripatetic days of the survey made the house in London a happy one which it was a privilege to enter, and when of late failing health led to Ramsay's withdrawal from London, he was tended with rare devotion and self-sacrifice.

Very special interest attaches to the beginning of his career, for it recalls the memory of one to whom the West of Scotland is under great obligations, but who is too little remembered now—John Pringle Nichol, the Professor of Astronomy. Ramsay came early under his influence; his teaching first gave him an interest in science, and the personal charm of the man raised interest into lasting enthusiasm. Nichol was a man of rare genius, of remarkable scientific insight; his poetic gifts, though they did not minister to technical accuracy, rendered him an interpreter of nature more persuasive, and, for his time, more useful than ampler detail of knowledge might have permitted him to be. Keenly alive to the progress of science, quick to recognise the directions in which the most rapid advances were likely to be made, he introduced to the notice of students in Glasgow the most recent novelties in theory or practice, sometimes before they were known in London. Thus Sir W. Thomson tells me that solid carbonic acid was seen in Glasgow four years before it was brought before the Royal Institution; but the remarkable thing is that Nichol, as if by intuition, rightly estimated researches which he could not have studied in detail—researches expressed in mathematical formulæ which only highly trained mathematicians could have followed. For the "Architecture of the Heavens," Ramsay prepared the

illustrations, and in later years he always gratefully acknowledged his obligations to one who had the magnetic gift of imparting his own enthusiasm. Others besides Ramsay felt this contagion, and I do not think I am wrong in saying that the existence and permanence of scientific societies in the West of Scotland was largely the work of this gifted man.

The British Association met in Glasgow in 1840, and in the preliminary arrangements Ramsay, at Nichol's instance, took an active share. That which determined his future life was his survey of Arran and the illustrative model now preserved in duplicate in the old Andersonian Museum and in Jermyn Street. It was indeed a remarkable piece of work for so young a man. Of field geology, as now understood, nothing was known in Glasgow, perhaps not even in Edinburgh. Almost simultaneously two men did parallel work—Maclaren, who wrote the geology of Fife and the Lothians, and Ramsay, who prepared his geology of Arran. The latter is the more noteworthy, for while Maclaren was in the city of Jamieson, and familiar with the work of Milne-Home, the brilliant R. J. H. Cunningham and others, who carried on the traditions of Hutton and Playfair, the Glasgow student had no such aid nor companionship. He had to plan and carry out his work on lines discovered for himself. Many years afterwards he said that there was much he would rewrite in his "Arran," but that referred specially to the question of the origin of the granites. Murchison, who at this meeting made his first acquaintance with Hugh Miller and Ramsay, recognised in the latter a man who might become a valuable associate. He was then planning an expedition to America, and invited Ramsay to join him, but he ultimately decided to return to Russia with De Verneuil and Von Keyserling; and, unable to carry out his plans with Ramsay, succeeded in securing him an appointment with Sir Henry de la Beche, who was then at Tenby carrying on the survey of the South-Western Counties. This was a most fortunate one for Ramsay and for British Geology. Sir Henry at once recognised a congenial spirit with whom he was thereafter closely allied during the rest of his life. Sir Henry has passed out of the knowledge of the younger geologists, who are not aware of the immense services which he rendered to geology. Of ancient descent and independent means, he commenced the survey at his own charges, and before he died saw it take its place as a national enterprise, not in the position best for it—that was not conquered

till later—but still so that its permanence and extension were safe. It was a brilliant company of young men whom he gathered about him, William Logan, Ramsay, Warrington Smyth, David Williams, Henry James, and later, Edward Forbes, Jukes, Oldham, Aveline, Selwyn—all men who afterwards rose to distinction. The life must have been a fascinating one, hard though the work was. Travelling was not so easy as it is now; accommodation was scanty; maps were not of the sort which now facilitate work. Yet the associations were delightful; surveying all day in the lovely scenery of Devonshire and Wales, at night the comparison of results and interchange of views; and when work was done, such talk as might be expected among young men all of more than average ability, culture, quickness of wit, and earnestness of purpose. In such company the Glasgow man must have found himself in a new atmosphere, mental and physical. Before joining, he had learned in London that scientific eminence was compatible with a very real enjoyment of life, and that the gaiety of heart and speech which were in Scotland scarcely deemed appropriate to the dignity of science, lightened labour, but did not diminish its amount or thoroughness. Sir Henry de la Beche was himself a bright leader, and a loved companion. The fine gentleman shone through all his actions, but his scientific power was even more striking. Those who, early in life, had the good fortune to make acquaintance with his “Geological Observer” will remember how fascinating that book was, how simple observation seemed, how direct and easy the inferences. The charm of his racy narrative, convincing without any pretence of eloquence, was enhanced by his admirable sketches, which formed a new feature in geological works, and replaced the quasi-geometric diagrams which it was so difficult to invest with the suggestion of natural scenery. But his simple-hearted devotion to the survey is that which has earned, but only scantily received, national gratitude. Attached to the Trigonometrical Survey—afterwards under the Board of Trade—it was not till 1855 that the survey was finally put under the Department of Science and Art, and if Lyon Playfair had had his way, it would have been a mere branch of what we now know as South Kensington. This De la Beche resisted successfully, to the annoyance of Prince Albert, whose memorandum conveys a regrettable disparagement, as an obstructionist of one idea, of a man who saw more clearly than himself that unification, as he proposed it, meant the strangling of some

of the units. I take this opportunity of recalling the memory of De la Beche, if for no other reason than that he assisted in making Ramsay, more rapidly than might otherwise have been the case, a leader in British geology. Ramsay's first important memoir, published in 1846, was on the Denudation of South Wales and the adjacent counties of England. It is modelled on the style of his chief, and is a worthy tribute to his memory. It shows the rare combination of close observation and careful reasoning which marked all his subsequent papers. It contains the germs of much subsequent work, for in those days there was little of the advertising by paper writing which burdens current literature with hasty work. Much of its value was due to the difficulties under which work was then conducted. Little could be put on a 1-inch map. The note-book was indispensable. The tradition then began of copious note-book treatises, but for which much valuable work would have been lost.

The Survey had begun to assume more important dimensions. In 1845 Sir H. de la Beche was appointed Director-General, and Ramsay and Captain Henry James the Local Directors for Great Britain and Ireland respectively. In 1847 Ramsay was appointed Professor of Geology in University College, and read himself in with a remarkable lecture on the history of his science—remarkable for so young a man who had been long engaged in field work. Associated with Edward Forbes in the close intimacy necessitated by survey life in Wales, his poetic and artistic tastes had been fostered by contact with the poet-naturalist, and to the communion he brought a mind prepared by study of the best English authors. From Forbes' letters it appears that the history of geology had engaged their attention, and the record of what had been done by earlier writers was no mere spurt of a man who wished to give a striking opening address. It was followed by a second historical lecture, and in after years he was wont to impress on his juniors the duty of making themselves familiar with what had been previously written. The University College Chair he held for three years, resigning it on his appointment as Professor of Geology in the School of Mines. In 1849 he had been elected a Fellow of the Royal Society. During his twenty years' tenure of the School of Mines Chair he lavished on his students the whole wealth of his knowledge and of his thoughts on geological subjects. Indeed, he was ever free with the results of his experience, which often gave material to less original

thinkers, who did not always acknowledge the source of their inspiration. I can only refer to a few of the lines which he struck out for himself. In the first years of his Survey work he saw and suggested the glacial origin of the Old Red Conglomerates, unaware at the time that Cumming, the Manx geologist, had already come to the same conclusion. He never lost sight of this subject. In after years he worked out the glacial origin of the Permian Conglomerates, and thus established the existence of land ice at that early date, though not the existence of the "glacial episode" which he speaks of in his "Physical Geography and Geology of Great Britain." Ice had a great attraction for him. In 1857 he was selected to represent British Geology at the American Association meeting, and in subsequent years he gave an account of Canadian glaciation, which he had studied under the guidance of Logan and James Hall. In his frequent visits to Switzerland he saw and noted much which he embodied in a paper published in "Peaks, Passes, and Glaciers." That paper was afterwards published separately, under the title of "Old Glaciers of Switzerland and Wales." The pencil which had illustrated Arran with charming and instructive vignettes lent interest to this volume by its pictures of Wales as it is, and of restorations of Wales as it might have been in glacial times. So well known was his interest in ice that Croll sent to him his first announcement of the hypothesis which now rules in geology, and the prompt generosity with which Ramsay introduced it to English science is worth noting. It is not usual for one trained to regard physical geography as dominant to acknowledge readily the value of an hypothesis which discounts physical geography. The inadequacy of Lyell's explanation of the glacial period was too obvious to one who taught as well as worked in the field, who had therefore an open mind for everything which gave prospect of a satisfactory solution. But the Director of the Survey learns officially, even if not naturally predisposed to it, that however absorbing one department of study may be, a certain perspective of studies must be kept in mind. Hence his keen interest in glacial action never blinded him to the fact that it was one only of the phenomena which might have occurred in any, and did occur in some bygone periods. To him the so-called ice age was not an epoch but an episode, and he distinctly on one occasion expressed that opinion: he meant it as a warning to his younger associates, who, he feared, were disposed to magnify

subordinate events unduly. Of this perception of perspective he gave another notable instance, when he spoke of the carboniferous limestone as an episode in palæozoic history. The full significance of this phrase can only be appreciated when we recall what he did in the matter of continental periods. Several brilliant papers are grouped round this question. He investigated the red rocks of several formations; he inquired into the lacustrine conditions under which they were deposited, and established the existence of continental periods in Western Europe, during one of which the carboniferous limestone sea invaded for a time the land.

These papers are such as could have been written only by one conversant with a wide range of phenomena, and able to generalise with accurate boldness regarding them. He had always the courage of his opinions, for these opinions were never hastily formed; and though regardful of those who had less knowledge than himself, he had not much tenderness for those who forgot the limits of their own ignorance, and especially intolerant was he of those who had "skill in doubting." A practised field surveyor, especially one who has had to superintend the details of section drawing, has many opportunities of realising the full bearings of phenomena, inexplicable when viewed only at one or two localities. To this source may be referred the important generalisation of plains of marine denudations, which he utilised in many ways. In brief terms he recognised that in regions undisturbed by recent cataclysms there was a general limit of the hill summits in height, so that, from the centre of the country to the sea margin, the highest points are successively lower, repeating exactly what may be seen on a rocky shore along the coast line. In this inclined plane he saw the slope of the emergent land, and this slope fixed the date of the river valleys as later than the emergence of the land. In Scotland, for example, the river valleys are carved out of this denudation plane, and the hill tops, gradually sinking towards the sea margin, are surviving portions of the original plain. It looks simple when thus summed up, yet it marked an important step in British geology. It bore fruit, too, in unexpected directions. The inquiry into the date of English rivers led to the opinion that the Severn had once drained the East of England, whose rivers later, when that eastern area had got inclined towards the present German Ocean, drained towards that sea. Similarly he worked out the history of the Rhine, not as a recent event, but as one of which explanation had to be

sought for first in miocene times. Of the origin of lakes he gave an account which, all things considered, will meet most of the cases. Criticism has been chiefly of the local sort. But the main principle stands as the recognition of the relations of these lakes to the radiation of ice from central high grounds which he had early recognised. In advancing this theory he curiously forgot his hearers' unfamiliarity with section drawing, and received aid from Huxley, who pointed out that the difficulties were lessened when the sections were drawn on true scale. A large amount of the opposition was due to the diagrammatic presentation of the results not on true scale. Whoever studies the charts of West Scotland is aware that the deepest parts of the lóchs are not at the mouths, but at some distance up the valley; that where two valleys meet, as do the upper reaches of Loch Long and Loch Gail, the deepest part of the joint-valley is not in the middle, but towards one side, just at the spot where the two glaciers would on junction exert their greatest pressure. The section of the Lake of Geneva given by De la Beche in his "Geological Observer" shows the same thing: so do the lakes of Sweden. It may be that a better theory than Ramsay's shall be discovered, but we have not yet got it, and it is significant that A. Geikie's text book does not refer to the captious critics, who with slender grasp of geological phenomena have measured a far-reaching generalisation by a few parochial observations.

The "Geology of Wales," published in 1866, is the record of years of labour, experience, and thought, such as in the present finds its British counterpart only in the researches of the Geological Survey in the extreme north of Scotland. Murchison well described it as the most important work issued by the Survey in his time of direction. It will ever remain a memorial of its author's capacity as a field observer and as an interpreter of complex phenomena.

The "Physical Geography and Geology of Great Britain" has run through five editions since the first sketch appeared in Blackie's "Encyclopædia." It is not a text book in the ordinary sense: Ramsay says it is not a record of what is common opinion, but the summary of his own experience and thought, and the verve with which it is written, though different, is comparable with that of the "Geological Observer." One is carried on from point to point, convinced for the moment by its author's enthusiasm, though not perhaps satisfied always with his arguments; but this

hesitation comes later. On one subject only does he fall short of his convictions—in the classification of the Cambro-Silurian strata. The wretched quarrel, fomented by one person above all others, between the great Cambridge geologist, Adam Sedgwick, and the great pioneer of continental geology, Murchison, is now forgotten—happily so. But it left its mark in the Survey maps, in which, naturally, Murchison's views find expression. Ramsay, partly out of loyalty to his old chief, has retained the Survey nomenclature, and has sacrificed something of his own views to the desire that his book should be a help, not a hindrance, to the study of the Survey maps.

But his grand work is the school of field geology, which, founded by De la Beche, he maintained and developed during his forty years of active work. The Survey influence extended far beyond its own ranks, and the papers submitted to the Geological Society attest the influence of methods which, for accuracy and thoroughness, are unsurpassed in any country.

As a lecturer, Ramsay was eminently successful. Abundant knowledge, wide experience, an accurate memory, and methodical habits of an unusual sort, secured the scientific value of his addresses, while the easy, natural flow of language, conversational in its simplicity and directness, interested the hearer by virtue of its spontaneity. But those who heard his addresses to the Royal Institution did not know how carefully they were planned. To each topic its due share of time was allotted, hence each received its due share of attention—none were omitted; and a sense of completeness was thereby left in the mind of the auditor, even of him who had little previous acquaintance with the subjects discussed.

His personality counted for very much: a handsome presence, a courtly manner, and a face whose mobility helped to emphasise his words, he seemed to me, when I first heard him nearly thirty years ago, a model scientific speaker. The simplicity of his address was not cultivated—it was the natural outcome of a genial nature, conscious that it had something to say worth listening to, but never properly conscious of its own power. He was capable of being dogmatic, but rarely so, and then only when compelled thereto by needless trifling or arrogant assumption on the part of opponents. His long and serious illness in 1860 told somewhat on him; he lost the unfailing geniality which met difficulties with a jest, and turned painful topics with a smile.

But to the last nervous suffering never impaired the real kindness of heart which was eminently characteristic of him. He never bore malice; unkindness might render him cool to those who had shown it, but never led him to repay it with its like. Ever ready to give information when it was asked—too ready, for he often gave away in a sentence the studies of years, to the betterment of his listener, though sometimes to his own loss; he was never soured by ingratitude, and the plagiarism of to-day did not prevent him from risking a similar return to-morrow. He is the last of the school of all-round geologists, who, like Logan, Jukes, and Oldham, took broad views of science, and never allowed a speciality to run away with them. To many, as to myself, his loss is a personal one; to science, his retirement was a still greater loss, for he ceased from work when, had health been granted him, he was best fitted to prove himself the greatest Scottish geologist since Playfair earned lasting fame as the interpreter of Hutton.

XVIII. — *On the late John Mossman, Hon. Royal Scottish Academician.* By THOMAS GILDARD, Architect.

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[Read before the Architectural Section, 14th March, 1892.]

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SEVERAL of you know, I dare say, that fully fifty years ago I entered on an apprenticeship with David Hamilton, the famous Glasgow architect. One of Mr. Hamilton's sons, who was a marble-cutter, had retired from business shortly before I entered the office, and for some time the father of the subject of this paper had been his working manager. When John Hamilton retired, Mossman's father began business for himself, his marble and monument works being at the corner of West Nile and Sauchiehall Streets, on the ground on which has been recently built a Methodist Chapel. It may be readily supposed that when Mr. Hamilton had a marble chimneypiece or other work to be executed, he employed the former manager for his son, and no less readily that I, then the boy in the office, would be the bearer of occasional messages. That is how I became acquainted with the Mossmans, and probably this acquaintance of half-a-century has indirectly—indirectly, because an expectation entertained last session was not realised—placed me in my present position of saying something, however briefly and inadequately, of one who was long and intimately associated with many Glasgow architects.

John Mossman was born in London, of Scottish parents, on 10th April, 1817, in the house of Allan Cunningham, author of "Lives of the British Painters," who was a fellow-worker with William Mossman in the studio of Sir Francis Chantrey. In 1820 William Mossman returned to Scotland, and began business in Edinburgh as a monumental sculptor. He came to Glasgow about 1831, and it was then that he undertook the management of Mr. Hamilton's marble works. When engaged in business on his own account he was largely employed on monumental work, and at few and far distant intervals he had an opportunity of cutting a bust of some public citizen. One of these busts was of David Hamilton, a better likeness I think than that by Patric Park in the Corporation Galleries, although possibly of

But to the last nervous suffering never ; there were two sons, ness of heart which was eminently initiated by their father never bore malice; unkindness mi- as were afforded by such had shown it, but never led ' of Grief, Hope, Patience, and ready to give information often gave away in ment of his list- never soured prevent hi- last of and

Edinburgh, where he remained about the Royal Scottish Academy under Sir after his return to Glasgow he designed work of any note, a nude winged figure Necropolis as a public monument to Peter a commission which he won in competition. Greenock monument to Burns's Highland a statue of John Henry Alexander, comedian, for his the Theatre Royal; also, one of the Reverend Patrick Brewster (brother of Sir David), for Paisley Public Cemetery. These were all of freestone, and he had some time to wait for his first statue in bronze. This was of Wilson, poet and ornithologist, and is erected in front of Paisley Abbey. Other bronze statues—Peel, Campbell, of the "Pleasures of Hope" (in the competition for which he defeated a leading London sculptor), and Livingstone, in George Square; Lord-Provost Lumsden and Norman Macleod, in Cathedral Square; A. B. Stewart (a Glasgow merchant), on the Esplanade, Rothesay; and George A. Clark (a Paisley thread manufacturer), in front of the George A. Clark Halls, Paisley,—followed in such rapid succession as might be reasonably expected in a city which, until the advent of Mossman, had given little attention to sculpture, or required to have its statues executed by others at a distance, such as Flaxman and Chantrey. One of his last works was a marble statue for Bombay.

Meanwhile Mr. Mossman had commissions for a large variety of work of a different character, chiefly sculpture upon public buildings. Of this kind of work he executed for Glasgow, and in freestone, six symbolic statues for the Glasgow and Ship (now Union) Bank, these being not only his first of that class, but of a comparative early period in his career: six statues, somewhat similar in character, armorial bearings, supported by emblematic figures, and a series of symbolic groups in panels for the old Municipal Buildings: statues of Homer, Cicero, Galileo, and Watt, on special pedestals of the High School: Flaxman, Wren, Purcell, and Reynolds, on the Athenæum, in St. George's Place: two

emblematic statues, and other decorative sculpture, for the Clydesdale Bank : a processional frieze, representing the progress of the fine and useful arts on front and principal side of the Queen's Rooms, and on this side representative medallion-traits, one over each of the seven windows—David Hamilton, representing Architecture ; Burns, Song, and so on—with (within semi-circular panel over transom or impost of windows) some characteristic emblem with foliage, as the Corinthian capital, and compasses and square, under Architecture ; the human eye, under Song, etc. : four groups of three figures each on St. Andrew's Halls—Homer, Dante, and Shakspeare—Buonarotti, Raphael, and Da Vinci—Pallas, Architecture, and Sculpture—three figures representative of Music—and eight caryatides : two symbolic statues and other symbolic sculptures, notably in the spandrels of semicircular-headed windows on the Municipal Buildings : two processional friezes, one showing oriental and the other occidental artists, and other sculptures, on the Fine Art Institute : a bust of the Queen, in a niche in the Corporation Galleries : and the Royal Arms (patriotic version) on the Crown Halls. The decorative statue in bronze and gilt, of the Lady of the Lake, surmounting the Waterworks Memorial Fountain in Kelvingrove Park, is Mossman's. For Greenock Municipal Buildings, Mr. Mossman executed, in freestone, a figure of Commerce (female seated), above the pediment of principal entrance ; four cantilever busts, two male and two female, representing the Seasons, and bas-relievos on spandrels of archway, representing Vulcan and Neptune.

His monumental, and especially his portrait busts, are numerous. Of the former, at least one is in bronze, that of Andrew Park, in Paisley Public Cemetery ; and of marble there may be mentioned Dr. Wardlaw (colossal), in the Fir Park Necropolis ; "Greek" Thomson in the Corporation Galleries ; Norman Macleod, Professor Eadie, and Sir Michael Shaw-Stewart, all of heroic size and for public purposes. Of private busts, one on the same scale was of Sheriff Bell. While possessing the higher qualities of the artist, Mossman eminently excelled in "catching a likeness," and, if some of his works were not the best fitted for the sculptor's chisel, they at least left it unmistakable portraits.

Mr. Mossman sometimes exercised himself on fanciful or ideal subjects, such as Rosalind and Portia, whom he represented by marble busts, and Moses (on the heroic scale), and "The

less value as a work of George and William Mossman. I have seen in his studio a tombstone which he had modelled for a public purpose what is into such a tombstone.

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He put into marble a large figure by Fillans, placed over Fillans's tomb in Paisley Public Cemetery. He did not largely exhibit, although his works were always welcome.

While Mr. Mossman was engaged on the statues for the Glasgow and Ship Bank—and that is fifty years ago—Baron Marochetti, then on a visit to Glasgow, saw a bust which he had put into marble, and was so pleased with it that he asked him to come to London to cut some for him there, one of which was of Andrew Stevenson Dalglish, brother of the late Robert Dalglish, M.P. Meanwhile the Baron had modelled a bust of Prince Albert, which he sent to Paris to be cut in marble by a carver whom he esteemed as the best in Europe. When it was returned and placed beside that of Mr. Dalglish, the Baron was so impressed by the superiority of Mossman's work that he caused the bust of the Prince to be done over again.

Mr. Mossman inherited from his father a considerable business in monumental sculpture, and in this and the work of the studio he was for many years associated in co-partnership with his brother George. Meanwhile the Mossmans had removed to the corner of North Frederick and Cathedral Streets, and there "J. & G. Mossman, sculptors," built a studio from a design by "Greek" Thomson. This building, not only characteristic of Thomson's genius at its best, but also costing a considerable sum, indicates the sympathy which the brothers Mossman had with the art of Architecture. After George's death the monument work was removed to some distance eastward in Cathedral Street, and there were then added to it all the appliances required in the cutting and polishing of granite, Mr. Mossman having excellent studios at his successive dwelling-houses, in Elmbank Crescent and in West Prince's Street. Besides these several studios and workshops, Mr. Mossman for a short time occupied a one-storey building in North Hanover Street. This was when with Buchan he was cutting the frieze for the Queen's Rooms. Many a time, long after midnight, I have kicked at the door, and, getting admission, have spent a pleasant hour with them gossiping about art or on the topics of the day.

Of the three brothers I knew George least. It was only a few years before his death, and during the occupancy of the "Greek" Thomson studio. I do not remember many of his works, but among them there are a military monument in the Cathedral, and a procession on a vase by "Greek" Thomson. His works are on a smaller scale than are many of John's, and are less heroic, but they have much grace and sentiment. While studying, or at work, in London—I am uncertain which—he was a competitor for a gold medal prize. When his work was finished he sent it by a porter to the place of exhibition, but while on its way it was let fall and broken into several pieces. Whether he put these together or remodelled the subject I do not know, but he again sent in his work, and with the result that he gained the prize. But the excitement consequent on the rapid succession of severe shock, anxious work, and ultimate success, it is feared so affected his health that throughout after-life he was often subject to serious illness. This prize work is, I believe, embedded in a wall of a staircase of what was once a residence, now a counting-house, in Glasgow, but a search that I made for it was unsuccessful. When George Mossman died, about a column of closely-printed matter was devoted to his memory by *The Art Journal*.

My acquaintanceship with William ("Bill," as he was familiarly called) began accidentally. He was engaged on a contract which John had with the city, and, while I was one day inspecting some other department of the works, he addressed me by name. He had lately returned from London, where for some years he had been working, first with Behnes, a famous bust sculptor, and latterly with Thomas, on the decorative statues of the Houses of Parliament. As has been said, he was working with John when I first met him, but he had at times a studio of his own, and at times again he was working with his brother. He was a man of great and varied ability, his work possessing much of the heroic dignity of John's, and the grace and tenderness of George's. The grand massive treatment, the gigantic power, in the Atlantes of the doorway to the Bank of Scotland surprised us; we were proud that we had such a Glasgow artist; and the same largeness of conception characterises the caryatides at the principal entrance to the St. Andrew's Halls. William himself had the contract for the bank, and John told me that the caryatides of the halls were wholly his brother's. In marked contrast to these are the bas-relief medallions on the offices of the Scottish Amicable

Assurance Company. At his death a brief obituary notice was sent to a Glasgow newspaper, in which it was mentioned that the extreme delicacy of the medallions had the praise of a no less able and severe critic than "Greek" Thomson; but the editorial judgment deemed that this was better—"they were very generally admired." Hamlet says something about the censure of one o'erweighing a whole theatre of others; and the press expects us to weigh being "very generally admired" with the opinion of one no less able as an art critic than as an architect. There can scarcely be any greater "damning with faint praise" of a work of sculpture than saying it has general admiration—the admiration of the ignorant and the vulgar. Similar in kind and excellence to these medallions are the sculptures on the Public Halls, Partick. The latest work on which William Mossman was engaged was a series of medallion-portraits in wax of eminent poets and others. These are of high merit, exceedingly spirited, and full of character. In conversing upon art he had a fine enthusiasm, which flowed in easy and appropriate language. His knowledge, while got much from books, was also obtained much from keen critical observation. To me it was always a delight to hear William Mossman speaking upon art.

There was another William Mossman, also a sculptor, John's son, who, after giving considerable promise, died comparatively young. He was sculptor of the bust of Shakspeare in the Corporation Galleries, for which he competed. Other works of his are a sitting figure of Falstaff, and a recumbent figure, "The Blind Beggar Boy."

About twenty years ago there were few grander-looking men in Glasgow than John Mossman. His head was of the same type as that of Longfellow—for whom, indeed, he once was mistaken; his figure was what may be called "manly," and his carriage of it was dignified, yet easy. His hair was of a kind beloved by poets and painters, of a rich golden colour, and slightly wavy, although in later life the golden had become silvern. I remember seeing him enter somewhat late a Fine Art Conversazione. He was, of course, in evening dress, and as he walked down the room he was "the observed of all observers." Had there been a stranger present Mr. Mossman's was the figure that would have first attracted him.

His portrait was often painted; indeed he must have been a splendid study for a young artist. Among the artists to whom

he sat, or in some instances stood, are the late Mr. Hutchison of the High School, Mr. Joseph Henderson, Mr. Greenlees, his daughter, Mrs. Wylie, Miss Sutcliffe, and last of all, Mr. Norman MacBeth. This portrait, which Mr. MacBeth presented to the Corporation Galleries, shows Mr. Mossman as "the grand old man," when age had mellowed and not withered. It is a most characteristic portrait, an admirable likeness, rich in colour, and well relieved from the few but appropriate accessories of its background. Those who had not the pleasure of knowing Mr. Mossman may form some idea of the man—I use "man" in the broadest sense—by looking at this portrait. The placing of this portrait among those of other distinguished Glasgow men, in the Corporation Galleries, and his election as an Honorary Royal Scottish Academician, are the chief public honours that have been bestowed upon him; and while we can scarcely apply the line by Johnson—"To buried merit raise the tardy bust," it seems strange that it was so late in life that his artistic status was recognised by the Academy.

Although possessing the advantages of a handsome presence, a gracious manner, a mind cultured not only by books but by travel and observation, and conversational powers alike easy and unaffected, Mr. Mossman was not what is called a "society" man. He could well take his place as a gentleman, and an artist of at least locally-recognised reputation in any drawing-room of West-End Glasgow, but social distinction he did not seem to covet; his pleasure was with one or two friends at his own fireside, or theirs; of even those art societies, of which he was, of course, a member, he was, I believe, not the most frequent attender. Amongst his most intimate friends and companions were the late Mr. Hutchison, Mr. Greenlees, Mr. D. P. Low, Mr. Brydall, and Mr. Joseph Henderson. I knew him perhaps longer than any of them, but visited him oftener when I had only to lift the "sneek" of the "Greek" Thomson studio than when I had to ring the front door bell at Elmbank Crescent or West Prince's Street. Perhaps his oldest friends were Mr. Baird, architect, and Miss Hamilton, daughter of the architect of the Royal Exchange.

Mr. Mossman was the connecting link of the present generation of Glasgow artists with that of the immediate past, and was rich in reminiscences of Wallace, Graham-Gilbert, Macnee, Milne Donald, Wighton, Macculloch, Sam Bough, Fillans, and others. When the full-size model of Fillans's magnificent sitting statue

was stored in an out-of-the-way place in Mr. Mossman's studio, I once expressed regret that, although I could see it generally, I could not see its face ; Mr. Mossman spoke of it in the highest praise, and said that I would see grace and tenderness in every line. He once asked me if I knew Sir John Steele ; on my replying in the negative, he said that the first time I was in Edinburgh I was to call, give him his compliments and ask to see the model of Alexander taming Bucephalus, adding that I would find Sir John one of the finest gentlemen I had ever met. I have been told that Mr. Mossman subscribed handsomely towards this group of sculpture being cast in bronze.

I remember of Mr. Mossman having heard of his old friend Buchan being in unprosperous circumstances in London. He immediately projected a scheme that might, while relieving Buchan, also possibly have spread and secured his reputation, but, before he had made much progress, poor Buchan was dead. At least one Glasgow paper paid a few lines of tribute to the memory of this most capable, but ill-starred artist.

I am not expected, I hope, to make any criticism. Although there are the same essential qualities in all works of art, poetry, music, sculpture, and architecture—such qualities as proportion, harmony, breadth, repose,—and, although I know perhaps something of their presence and co-relation in at least one of these arts, I am not sufficiently acquainted with the particular conditions of sculpture to allow me to offer any critical deliverance. Sculpture is an ideal art, and ought so to be considered ; or, it rather *was*, for in our time it has been lowered to realism, its most common use being to present the *vera effigies*, in his habit as he lived, of the local “man you know,” as well as the semblance of some statesman, poet, or philosopher of world-wide celebrity. For some people it is very apparent that sculpture was no more intended than were they intended for sculpture, and, consequently, the consideration of the quality of the statues of those of commonplace features and figure is very limited—to whether or not there is a good likeness. Sculpture, even on prosaic subjects, is more ideal than painting. It differs from painting in that it is independent of colour, and that in many positions it can be seen all round. Bronze not admitting of much delicacy of light and shade, a statue in that material requires strong outline and vigorous modelling, and, if placed in an isolated situation, a statue so dependent upon outline may, from some point of view, appear as

if about to step down from the sublime to the ridiculous. Some of us have, I dare say, seen black statues with very pronounced outlines that, from certain standpoints, seemed as if approaching the grotesque.

Without going so far as to say that "familiarity breeds contempt," it may, I think, be safely admitted that the familiar is not conducive towards the highest art. Until of late, modern costume was designedly eschewed, and sculptors still gladly avail themselves of any opportunity for draping. One of Mossman's best statues, that of Lumsden, is in modern costume. In this, however, the overcoat is so treated as to give picturesqueness to the figure without impairing the dignity of statuesque repose. I was present at the unveiling of this statue, and, by either accident or design, was near enough to the late George Ewing to hear what he was saying to a little group of eager listeners. He said he had looked at that statue from all available points—one, unfortunately, he could not command—and that, what few statues did, it looked well from all; and I heard him again say that, of course, Flaxman's Moore was the finest statue in Glasgow—Mr. Sellars thought in Europe—and that Mossman's Lumsden was next. Another, an earlier statue, that of Peel, is also in modern costume, but, having not even the draping accessory of an overcoat, looks somewhat attenuated; it, however, led a stranger in one of the George Square hotels to ask who was the sculptor, and to say that of all statues of Peel it was the most characteristic. Several of his other bronze statues are favoured by draping, consequent upon the accidental circumstance of unfamiliar fashion or official position. Such are those of Wilson, Campbell, Livingstone, and Norman Macleod. His Wilson, while picturesque, at the same time satisfying the severer canons of sculpture, appeals to all critics as a work of the very highest excellence. It has been engraved in *The Illustrated London News*. It was at first intended that the statue of Dr. Macleod should be a sitting figure of marble, and placed within the Cathedral, and, in accordance with this intention, Mr. Mossman made a model. Considering the grand presence of Macleod, he was better pleased with the idea of a standing attitude, more favourable to the representation of the subject and to the opportunity for the artist. The costume of Moderator of the General Assembly of the Church of Scotland supplies drapery singularly in keeping with the grand, manly figure of the minister of the Barony.

But to the last nervous suffering never impaired the real kindness of heart which was eminently characteristic of him. He never bore malice; unkindness might render him cool to those who had shown it, but never led him to repay it with its like. Ever ready to give information when it was asked—too ready, for he often gave away in a sentence the studies of years, to the betterment of his listener, though sometimes to his own loss; he was never soured by ingratitude, and the plagiarism of to-day did not prevent him from risking a similar return to-morrow. He is the last of the school of all-round geologists, who, like Logan, Jukes, and Oldham, took broad views of science, and never allowed a speciality to run away with them. To many, as to myself, his loss is a personal one; to science, his retirement was a still greater loss, for he ceased from work when, had health been granted him, he was best fitted to prove himself the greatest Scottish geologist since Playfair earned lasting fame as the interpreter of Hutton.

XVIII. — *On the late John Mossman, Hon. Royal Scottish Academician.* By THOMAS GILDARD, Architect.

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[Read before the Architectural Section, 14th March, 1892.]

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SEVERAL of you know, I dare say, that fully fifty years ago I entered on an apprenticeship with David Hamilton, the famous Glasgow architect. One of Mr. Hamilton's sons, who was a marble-cutter, had retired from business shortly before I entered the office, and for some time the father of the subject of this paper had been his working manager. When John Hamilton retired, Mossman's father began business for himself, his marble and monument works being at the corner of West Nile and Sauchiehall Streets, on the ground on which has been recently built a Methodist Chapel. It may be readily supposed that when Mr. Hamilton had a marble chimneypiece or other work to be executed, he employed the former manager for his son, and no less readily that I, then the boy in the office, would be the bearer of occasional messages. That is how I became acquainted with the Mossmans, and probably this acquaintance of half-a-century has indirectly—indirectly, because an expectation entertained last session was not realised—placed me in my present position of saying something, however briefly and inadequately, of one who was long and intimately associated with many Glasgow architects.

John Mossman was born in London, of Scottish parents, on 10th April, 1817, in the house of Allan Cunningham, author of "Lives of the British Painters," who was a fellow-worker with William Mossman in the studio of Sir Francis Chantrey. In 1820 William Mossman returned to Scotland, and began business in Edinburgh as a monumental sculptor. He came to Glasgow about 1831, and it was then that he undertook the management of Mr. Hamilton's marble works. When engaged in business on his own account he was largely employed on monumental work, and at few and far distant intervals he had an opportunity of cutting a bust of some public citizen. One of these busts was of David Hamilton, a better likeness I think than that by Patric Park in the Corporation Galleries, although possibly of

till later—but still so that its permanence and extension were safe. It was a brilliant company of young men whom he gathered about him, William Logan, Ramsay, Warrington Smyth, David Williams, Henry James, and later, Edward Forbes, Jukes, Oldham, Aveline, Selwyn—all men who afterwards rose to distinction. The life must have been a fascinating one, hard though the work was. Travelling was not so easy as it is now; accommodation was scanty; maps were not of the sort which now facilitate work. Yet the associations were delightful; surveying all day in the lovely scenery of Devonshire and Wales, at night the comparison of results and interchange of views; and when work was done, such talk as might be expected among young men all of more than average ability, culture, quickness of wit, and earnestness of purpose. In such company the Glasgow man must have found himself in a new atmosphere, mental and physical. Before joining, he had learned in London that scientific eminence was compatible with a very real enjoyment of life, and that the gaiety of heart and speech which were in Scotland scarcely deemed appropriate to the dignity of science, lightened labour, but did not diminish its amount or thoroughness. Sir Henry de la Beche was himself a bright leader, and a loved companion. The fine gentleman shone through all his actions, but his scientific power was even more striking. Those who, early in life, had the good fortune to make acquaintance with his “Geological Observer” will remember how fascinating that book was, how simple observation seemed, how direct and easy the inferences. The charm of his racy narrative, convincing without any pretence of eloquence, was enhanced by his admirable sketches, which formed a new feature in geological works, and replaced the quasi-geometric diagrams which it was so difficult to invest with the suggestion of natural scenery. But his simple-hearted devotion to the survey is that which has earned, but only scantily received, national gratitude. Attached to the Trigonometrical Survey—afterwards under the Board of Trade—it was not till 1855 that the survey was finally put under the Department of Science and Art, and if Lyon Playfair had had his way, it would have been a mere branch of what we now know as South Kensington. This De la Beche resisted successfully, to the annoyance of Prince Albert, whose memorandum conveys a regrettable disparagement, as an obstructionist of one idea, of a man who saw more clearly than himself that unification, as he proposed it, meant the strangling of some

of the units. I take this opportunity of recalling the memory of De la Beche, if for no other reason than that he assisted in making Ramsay, more rapidly than might otherwise have been the case, a leader in British geology. Ramsay's first important memoir, published in 1846, was on the Denudation of South Wales and the adjacent counties of England. It is modelled on the style of his chief, and is a worthy tribute to his memory. It shows the rare combination of close observation and careful reasoning which marked all his subsequent papers. It contains the germs of much subsequent work, for in those days there was little of the advertising by paper writing which burdens current literature with hasty work. Much of its value was due to the difficulties under which work was then conducted. Little could be put on a 1-inch map. The note-book was indispensable. The tradition then began of copious note-book treatises, but for which much valuable work would have been lost.

The Survey had begun to assume more important dimensions. In 1845 Sir H. de la Beche was appointed Director-General, and Ramsay and Captain Henry James the Local Directors for Great Britain and Ireland respectively. In 1847 Ramsay was appointed Professor of Geology in University College, and read himself in with a remarkable lecture on the history of his science—remarkable for so young a man who had been long engaged in field work. Associated with Edward Forbes in the close intimacy necessitated by survey life in Wales, his poetic and artistic tastes had been fostered by contact with the poet-naturalist, and to the communion he brought a mind prepared by study of the best English authors. From Forbes' letters it appears that the history of geology had engaged their attention, and the record of what had been done by earlier writers was no mere spurt of a man who wished to give a striking opening address. It was followed by a second historical lecture, and in after years he was wont to impress on his juniors the duty of making themselves familiar with what had been previously written. The University College Chair he held for three years, resigning it on his appointment as Professor of Geology in the School of Mines. In 1849 he had been elected a Fellow of the Royal Society. During his twenty years' tenure of the School of Mines Chair he lavished on his students the whole wealth of his knowledge and of his thoughts on geological subjects. Indeed, he was ever free with the results of his experience, which often gave material to less original

thinkers, who did not always acknowledge the source of their inspiration. I can only refer to a few of the lines which he struck out for himself. In the first years of his Survey work he saw and suggested the glacial origin of the Old Red Conglomerates, unaware at the time that Cumming, the Manx geologist, had already come to the same conclusion. He never lost sight of this subject. In after years he worked out the glacial origin of the Permian Conglomerates, and thus established the existence of land ice at that early date, though not the existence of the "glacial episode" which he speaks of in his "Physical Geography and Geology of Great Britain." Ice had a great attraction for him. In 1857 he was selected to represent British Geology at the American Association meeting, and in subsequent years he gave an account of Canadian glaciation, which he had studied under the guidance of Logan and James Hall. In his frequent visits to Switzerland he saw and noted much which he embodied in a paper published in "Peaks, Passes, and Glaciers." That paper was afterwards published separately, under the title of "Old Glaciers of Switzerland and Wales." The pencil which had illustrated Arran with charming and instructive vignettes lent interest to this volume by its pictures of Wales as it is, and of restorations of Wales as it might have been in glacial times. So well known was his interest in ice that Croll sent to him his first announcement of the hypothesis which now rules in geology, and the prompt generosity with which Ramsay introduced it to English science is worth noting. It is not usual for one trained to regard physical geography as dominant to acknowledge readily the value of an hypothesis which discounts physical geography. The inadequacy of Lyell's explanation of the glacial period was too obvious to one who taught as well as worked in the field, who had therefore an open mind for everything which gave prospect of a satisfactory solution. But the Director of the Survey learns officially, even if not naturally predisposed to it, that however absorbing one department of study may be, a certain perspective of studies must be kept in mind. Hence his keen interest in glacial action never blinded him to the fact that it was one only of the phenomena which might have occurred in any, and did occur in some bygone periods. To him the so-called ice age was not an epoch but an episode, and he distinctly on one occasion expressed that opinion: he meant it as a warning to his younger associates, who, he feared, were disposed to magnify

subordinate events unduly. Of this perception of perspective he gave another notable instance, when he spoke of the carboniferous limestone as an episode in palæozoic history. The full significance of this phrase can only be appreciated when we recall what he did in the matter of continental periods. Several brilliant papers are grouped round this question. He investigated the red rocks of several formations; he inquired into the lacustrine conditions under which they were deposited, and established the existence of continental periods in Western Europe, during one of which the carboniferous limestone sea invaded for a time the land.

These papers are such as could have been written only by one conversant with a wide range of phenomena, and able to generalise with accurate boldness regarding them. He had always the courage of his opinions, for these opinions were never hastily formed; and though regardful of those who had less knowledge than himself, he had not much tenderness for those who forgot the limits of their own ignorance, and especially intolerant was he of those who had "skill in doubting." A practised field surveyor, especially one who has had to superintend the details of section drawing, has many opportunities of realising the full bearings of phenomena, inexplicable when viewed only at one or two localities. To this source may be referred the important generalisation of plains of marine denudations, which he utilised in many ways. In brief terms he recognised that in regions undisturbed by recent cataclysms there was a general limit of the hill summits in height, so that, from the centre of the country to the sea margin, the highest points are successively lower, repeating exactly what may be seen on a rocky shore along the coast line. In this inclined plane he saw the slope of the emergent land, and this slope fixed the date of the river valleys as later than the emergence of the land. In Scotland, for example, the river valleys are carved out of this denudation plane, and the hill tops, gradually sinking towards the sea margin, are surviving portions of the original plain. It looks simple when thus summed up, yet it marked an important step in British geology. It bore fruit, too, in unexpected directions. The inquiry into the date of English rivers led to the opinion that the Severn had once drained the East of England, whose rivers later, when that eastern area had got inclined towards the present German Ocean, drained towards that sea. Similarly he worked out the history of the Rhine, not as a recent event, but as one of which explanation had to be

sought for first in miocene times. Of the origin of lakes he gave an account which, all things considered, will meet most of the cases. Criticism has been chiefly of the local sort. But the main principle stands as the recognition of the relations of these lakes to the radiation of ice from central high grounds which he had early recognised. In advancing this theory he curiously forgot his hearers' unfamiliarity with section drawing, and received aid from Huxley, who pointed out that the difficulties were lessened when the sections were drawn on true scale. A large amount of the opposition was due to the diagrammatic presentation of the results not on true scale. Whoever studies the charts of West Scotland is aware that the deepest parts of the lochs are not at the mouths, but at some distance up the valley; that where two valleys meet, as do the upper reaches of Loch Long and Loch Gail, the deepest part of the joint-valley is not in the middle, but towards one side, just at the spot where the two glaciers would on junction exert their greatest pressure. The section of the Lake of Geneva given by De la Beche in his "Geological Observer" shows the same thing: so do the lakes of Sweden. It may be that a better theory than Ramsay's shall be discovered, but we have not yet got it, and it is significant that A. Geikie's text book does not refer to the captious critics, who with slender grasp of geological phenomena have measured a far-reaching generalisation by a few parochial observations.

The "Geology of Wales," published in 1866, is the record of years of labour, experience, and thought, such as in the present finds its British counterpart only in the researches of the Geological Survey in the extreme north of Scotland. Murchison well described it as the most important work issued by the Survey in his time of direction. It will ever remain a memorial of its author's capacity as a field observer and as an interpreter of complex phenomena.

The "Physical Geography and Geology of Great Britain" has run through five editions since the first sketch appeared in Blackie's "Encyclopædia." It is not a text book in the ordinary sense: Ramsay says it is not a record of what is common opinion, but the summary of his own experience and thought, and the verve with which it is written, though different, is comparable with that of the "Geological Observer." One is carried on from point to point, convinced for the moment by its author's enthusiasm, though not perhaps satisfied always with his arguments; but this

hesitation comes later. On one subject only does he fall short of his convictions—in the classification of the Cambro-Silurian strata. The wretched quarrel, fomented by one person above all others, between the great Cambridge geologist, Adam Sedgwick, and the great pioneer of continental geology, Murchison, is now forgotten—happily so. But it left its mark in the Survey maps, in which, naturally, Murchison's views find expression. Ramsay, partly out of loyalty to his old chief, has retained the Survey nomenclature, and has sacrificed something of his own views to the desire that his book should be a help, not a hindrance, to the study of the Survey maps.

But his grand work is the school of field geology, which, founded by De la Beche, he maintained and developed during his forty years of active work. The Survey influence extended far beyond its own ranks, and the papers submitted to the Geological Society attest the influence of methods which, for accuracy and thoroughness, are unsurpassed in any country.

As a lecturer, Ramsay was eminently successful. Abundant knowledge, wide experience, an accurate memory, and methodical habits of an unusual sort, secured the scientific value of his addresses, while the easy, natural flow of language, conversational in its simplicity and directness, interested the hearer by virtue of its spontaneity. But those who heard his addresses to the Royal Institution did not know how carefully they were planned. To each topic its due share of time was allotted, hence each received its due share of attention—none were omitted; and a sense of completeness was thereby left in the mind of the auditor, even of him who had little previous acquaintance with the subjects discussed.

His personality counted for very much: a handsome presence, a courtly manner, and a face whose mobility helped to emphasise his words, he seemed to me, when I first heard him nearly thirty years ago, a model scientific speaker. The simplicity of his address was not cultivated—it was the natural outcome of a genial nature, conscious that it had something to say worth listening to, but never properly conscious of its own power. He was capable of being dogmatic, but rarely so, and then only when compelled thereto by needless trifling or arrogant assumption on the part of opponents. His long and serious illness in 1860 told somewhat on him; he lost the unfailing geniality which met difficulties with a jest, and turned painful topics with a smile.

But to the last nervous suffering never impaired the real kindness of heart which was eminently characteristic of him. He never bore malice; unkindness might render him cool to those who had shown it, but never led him to repay it with its like. Ever ready to give information when it was asked—too ready, for he often gave away in a sentence the studies of years, to the betterment of his listener, though sometimes to his own loss; he was never soured by ingratitude, and the plagiarism of to-day did not prevent him from risking a similar return to-morrow. He is the last of the school of all-round geologists, who, like Logan, Jukes, and Oldham, took broad views of science, and never allowed a speciality to run away with them. To many, as to myself, his loss is a personal one; to science, his retirement was a still greater loss, for he ceased from work when, had health been granted him, he was best fitted to prove himself the greatest Scottish geologist since Playfair earned lasting fame as the interpreter of Hutton.

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less value as a work of art. Besides John, there were two sons, George and William, and all were early initiated by their father into such technics of the glyptic art as were afforded by such tombstone accessories as figures of Grief, Hope, Patience, and Resignation.

In 1838 John went to Edinburgh, where he remained about one year, studying at the Royal Scottish Academy under Sir William Allan. Shortly after his return to Glasgow he designed and executed his earliest work of any note, a nude winged figure erected in the Fir Park Necropolis as a public monument to Peter Lawrence, sculptor, a commission which he won in competition. Then followed the Greenock monument to Burns's Highland Mary, and a statue of John Henry Alexander, comedian, for his own property, the Theatre Royal; also, one of the Reverend Patrick Brewster (brother of Sir David), for Paisley Public Cemetery. These were all of freestone, and he had some time to wait for his first statue in bronze. This was of Wilson, poet and ornithologist, and is erected in front of Paisley Abbey. Other bronze statues—Peel, Campbell, of the "Pleasures of Hope" (in the competition for which he defeated a leading London sculptor), and Livingstone, in George Square; Lord-Provost Lumsden and Norman Macleod, in Cathedral Square; A. B. Stewart (a Glasgow merchant), on the Esplanade, Rothesay; and George A. Clark (a Paisley thread manufacturer), in front of the George A. Clark Halls, Paisley,—followed in such rapid succession as might be reasonably expected in a city which, until the advent of Mossman, had given little attention to sculpture, or required to have its statues executed by others at a distance, such as Flaxman and Chantrey. One of his last works was a marble statue for Bombay.

Meanwhile Mr. Mossman had commissions for a large variety of work of a different character, chiefly sculpture upon public buildings. Of this kind of work he executed for Glasgow, and in freestone, six symbolic statues for the Glasgow and Ship (now Union) Bank, these being not only his first of that class, but of a comparative early period in his career: six statues, somewhat similar in character, armorial bearings, supported by emblematic figures, and a series of symbolic groups in panels for the old Municipal Buildings: statues of Homer, Cicero, Galileo, and Watt, on special pedestals of the High School: Flaxman, Wren, Purcell, and Reynolds, on the Athenæum, in St. George's Place: two

emblematic statues, and other decorative sculpture, for the Clydesdale Bank : a processional frieze, representing the progress of the fine and useful arts on front and principal side of the Queen's Rooms, and on this side representative medallion-portraits, one over each of the seven windows—David Hamilton, representing Architecture ; Burns, Song, and so on—with (within semi-circular panel over transom or impost of windows) some characteristic emblem with foliage, as the Corinthian capital, and compasses and square, under Architecture ; the human eye, under Song, etc. : four groups of three figures each on St. Andrew's Halls—Homer, Dante, and Shakspeare—Buonarotti, Raphael, and Da Vinci—Pallas, Architecture, and Sculpture—three figures representative of Music—and eight caryatides : two symbolic statues and other symbolic sculptures, notably in the spandrels of semicircular-headed windows on the Municipal Buildings : two processional friezes, one showing oriental and the other occidental artists, and other sculptures, on the Fine Art Institute : a bust of the Queen, in a niche in the Corporation Galleries : and the Royal Arms (patriotic version) on the Crown Halls. The decorative statue in bronze and gilt, of the Lady of the Lake, surmounting the Waterworks Memorial Fountain in Kelvingrove Park, is Mossman's. For Greenock Municipal Buildings, Mr. Mossman executed, in freestone, a figure of Commerce (female seated), above the pediment of principal entrance ; four cantilever busts, two male and two female, representing the Seasons, and bas-relievos on spandrels of archway, representing Vulcan and Neptune.

His monumental, and especially his portrait busts, are numerous. Of the former, at least one is in bronze, that of Andrew Park, in Paisley Public Cemetery ; and of marble there may be mentioned Dr. Wardlaw (colossal), in the Fir Park Necropolis ; "Greek" Thomson in the Corporation Galleries ; Norman Macleod, Professor Eadie, and Sir Michael Shaw-Stewart, all of heroic size and for public purposes. Of private busts, one on the same scale was of Sheriff Bell. While possessing the higher qualities of the artist, Mossman eminently excelled in "catching a likeness," and, if some of his works were not the best fitted for the sculptor's chisel, they at least left it unmistakable portraits.

Mr. Mossman sometimes exercised himself on fanciful or ideal subjects, such as Rosalind and Portia, whom he represented by marble busts, and Moses (on the heroic scale), and "The

Of the three brothers I knew George least. It was only a few years before his death, and during the occupancy of the "Greek" Thomson studio. I do not remember many of his works, but among them there are a military monument in the Cathedral, and a procession on a vase by "Greek" Thomson. His works are on a smaller scale than are many of John's, and are less heroic, but they have much grace and sentiment. While studying, or at work, in London—I am uncertain which—he was a competitor for a gold medal prize. When his work was finished he sent it by a porter to the place of exhibition, but while on its way it was let fall and broken into several pieces. Whether he put these together or remodelled the subject I do not know, but he again sent in his work, and with the result that he gained the prize. But the excitement consequent on the rapid succession of severe shock, anxious work, and ultimate success, it is feared so affected his health that throughout after-life he was often subject to serious illness. This prize work is, I believe, embedded in a wall of a staircase of what was once a residence, now a counting-house, in Glasgow, but a search that I made for it was unsuccessful. When George Mossman died, about a column of closely-printed matter was devoted to his memory by *The Art Journal*.

My acquaintanceship with William ("Bill," as he was familiarly called) began accidentally. He was engaged on a contract which John had with the city, and, while I was one day inspecting some other department of the works, he addressed me by name. He had lately returned from London, where for some years he had been working, first with Behnes, a famous bust sculptor, and latterly with Thomas, on the decorative statues of the Houses of Parliament. As has been said, he was working with John when I first met him, but he had at times a studio of his own, and at times again he was working with his brother. He was a man of great and varied ability, his work possessing much of the heroic dignity of John's, and the grace and tenderness of George's. The grand massive treatment, the gigantic power, in the Atlantes of the doorway to the Bank of Scotland surprised us; we were proud that we had such a Glasgow artist; and the same largeness of conception characterises the caryatides at the principal entrance to the St. Andrew's Halls. William himself had the contract for the bank, and John told me that the caryatides of the halls were wholly his brother's. In marked contrast to these are the bas-relief medallions on the offices of the Scottish Amicable

Assurance Company. At his death a brief obituary notice was sent to a Glasgow newspaper, in which it was mentioned that the extreme delicacy of the medallions had the praise of a no less able and severe critic than "Greek" Thomson; but the editorial judgment deemed that this was better—"they were very generally admired." Hamlet says something about the censure of one o'erweighing a whole theatre of others; and the press expects us to weigh being "very generally admired" with the opinion of one no less able as an art critic than as an architect. There can scarcely be any greater "damning with faint praise" of a work of sculpture than saying it has general admiration—the admiration of the ignorant and the vulgar. Similar in kind and excellence to these medallions are the sculptures on the Public Halls, Partick. The latest work on which William Mossman was engaged was a series of medallion-portraits in wax of eminent poets and others. These are of high merit, exceedingly spirited, and full of character. In conversing upon art he had a fine enthusiasm, which flowed in easy and appropriate language. His knowledge, while got much from books, was also obtained much from keen critical observation. To me it was always a delight to hear William Mossman speaking upon art.

There was another William Mossman, also a sculptor, John's son, who, after giving considerable promise, died comparatively young. He was sculptor of the bust of Shakspeare in the Corporation Galleries, for which he competed. Other works of his are a sitting figure of Falstaff, and a recumbent figure, "The Blind Beggar Boy."

About twenty years ago there were few grander-looking men in Glasgow than John Mossman. His head was of the same type as that of Longfellow—for whom, indeed, he once was mistaken; his figure was what may be called "manly," and his carriage of it was dignified, yet easy. His hair was of a kind beloved by poets and painters, of a rich golden colour, and slightly wavy, although in later life the golden had become silvern. I remember seeing him enter somewhat late a Fine Art Conversazione. He was, of course, in evening dress, and as he walked down the room he was "the observed of all observers." Had there been a stranger present Mr. Mossman's was the figure that would have first attracted him.

His portrait was often painted; indeed he must have been a splendid study for a young artist. Among the artists to whom

he sat, or in some instances stood, are the late Mr. Hutchison of the High School, Mr. Joseph Henderson, Mr. Greenlees, his daughter, Mrs. Wylie, Miss Sutcliffe, and last of all, Mr. Norman MacBeth. This portrait, which Mr. MacBeth presented to the Corporation Galleries, shows Mr. Mossman as "the grand old man," when age had mellowed and not withered. It is a most characteristic portrait, an admirable likeness, rich in colour, and well relieved from the few but appropriate accessories of its background. Those who had not the pleasure of knowing Mr. Mossman may form some idea of the man—I use "man" in the broadest sense—by looking at this portrait. The placing of this portrait among those of other distinguished Glasgow men, in the Corporation Galleries, and his election as an Honorary Royal Scottish Academician, are the chief public honours that have been bestowed upon him; and while we can scarcely apply the line by Johnson—"To buried merit raise the tardy bust," it seems strange that it was so late in life that his artistic status was recognised by the Academy.

Although possessing the advantages of a handsome presence, a gracious manner, a mind cultured not only by books but by travel and observation, and conversational powers alike easy and unaffected, Mr. Mossman was not what is called a "society" man. He could well take his place as a gentleman, and an artist of at least locally-recognised reputation in any drawing-room of West-End Glasgow, but social distinction he did not seem to covet; his pleasure was with one or two friends at his own fireside, or theirs; of even those art societies, of which he was, of course, a member, he was, I believe, not the most frequent attender. Amongst his most intimate friends and companions were the late Mr. Hutchison, Mr. Greenlees, Mr. D. P. Low, Mr. Brydall, and Mr. Joseph Henderson. I knew him perhaps longer than any of them, but visited him oftener when I had only to lift the "sneek" of the "Greek" Thomson studio than when I had to ring the front door bell at Elmbank Crescent or West Prince's Street. Perhaps his oldest friends were Mr. Baird, architect, and Miss Hamilton, daughter of the architect of the Royal Exchange.

Mr. Mossman was the connecting link of the present generation of Glasgow artists with that of the immediate past, and was rich in reminiscences of Wallace, Graham-Gilbert, Macnee, Milne Donald, Wighton, Macculloch, Sam Bough, Fillans, and others. When the full-size model of Fillans's magnificent sitting statue

was stored in an out-of-the-way place in Mr. Mossman's studio, I once expressed regret that, although I could see it generally, I could not see its face ; Mr. Mossman spoke of it in the highest praise, and said that I would see grace and tenderness in every line. He once asked me if I knew Sir John Steele ; on my replying in the negative, he said that the first time I was in Edinburgh I was to call, give him his compliments and ask to see the model of Alexander taming Bucephalus, adding that I would find Sir John one of the finest gentlemen I had ever met. I have been told that Mr. Mossman subscribed handsomely towards this group of sculpture being cast in bronze.

I remember of Mr. Mossman having heard of his old friend Buchan being in unprosperous circumstances in London. He immediately projected a scheme that might, while relieving Buchan, also possibly have spread and secured his reputation, but, before he had made much progress, poor Buchan was dead. At least one Glasgow paper paid a few lines of tribute to the memory of this most capable, but ill-starred artist.

I am not expected, I hope, to make any criticism. Although there are the same essential qualities in all works of art, poetry, music, sculpture, and architecture—such qualities as proportion, harmony, breadth, repose,—and, although I know perhaps something of their presence and co-relation in at least one of these arts, I am not sufficiently acquainted with the particular conditions of sculpture to allow me to offer any critical deliverance. Sculpture is an ideal art, and ought so to be considered ; or, it rather *was*, for in our time it has been lowered to realism, its most common use being to present the *vera effigies*, in his habit as he lived, of the local “man you know,” as well as the semblance of some statesman, poet, or philosopher of world-wide celebrity. For some people it is very apparent that sculpture was no more intended than were they intended for sculpture, and, consequently, the consideration of the quality of the statues of those of commonplace features and figure is very limited—to whether or not there is a good likeness. Sculpture, even on prosaic subjects, is more ideal than painting. It differs from painting in that it is independent of colour, and that in many positions it can be seen all round. Bronze not admitting of much delicacy of light and shade, a statue in that material requires strong outline and vigorous modelling, and, if placed in an isolated situation, a statue so dependent upon outline may, from some point of view, appear as

if about to step down from the sublime to the ridiculous. Some of us have, I dare say, seen black statues with very pronounced outlines that, from certain standpoints, seemed as if approaching the grotesque.

Without going so far as to say that "familiarity breeds contempt," it may, I think, be safely admitted that the familiar is not conducive towards the highest art. Until of late, modern costume was designedly eschewed, and sculptors still gladly avail themselves of any opportunity for draping. One of Mossman's best statues, that of Lumsden, is in modern costume. In this, however, the overcoat is so treated as to give picturesqueness to the figure without impairing the dignity of statuesque repose. I was present at the unveiling of this statue, and, by either accident or design, was near enough to the late George Ewing to hear what he was saying to a little group of eager listeners. He said he had looked at that statue from all available points—one, unfortunately, he could not command—and that, what few statues did, it looked well from all; and I heard him again say that, of course, Flaxman's Moore was the finest statue in Glasgow—Mr. Sellars thought in Europe—and that Mossman's Lumsden was next. Another, an earlier statue, that of Peel, is also in modern costume, but, having not even the draping accessory of an overcoat, looks somewhat attenuated; it, however, led a stranger in one of the George Square hotels to ask who was the sculptor, and to say that of all statues of Peel it was the most characteristic. Several of his other bronze statues are favoured by draping, consequent upon the accidental circumstance of unfamiliar fashion or official position. Such are those of Wilson, Campbell, Livingstone, and Norman Macleod. His Wilson, while picturesque, at the same time satisfying the severer canons of sculpture, appeals to all critics as a work of the very highest excellence. It has been engraved in *The Illustrated London News*. It was at first intended that the statue of Dr. Macleod should be a sitting figure of marble, and placed within the Cathedral, and, in accordance with this intention, Mr. Mossman made a model. Considering the grand presence of Macleod, he was better pleased with the idea of a standing attitude, more favourable to the representation of the subject and to the opportunity for the artist. The costume of Moderator of the General Assembly of the Church of Scotland supplies drapery singularly in keeping with the grand, manly figure of the minister of the Barony.

Of busts I will only mention that of "Greek" Thomson. For this he got marble specially from Greece, but somehow it was unsuitable. One who had never seen Thomson exclaimed, when he first saw this bust, "No wonder he was great in Greek art, he was himself a Greek." After, with some little ceremonial, it was presented to the city, a local weekly journal wrote:—

As Thomson's cultur'd genius, ripe as rare,  
Greek grace and grandeur could conceive, express,  
As own might Athens in her prime—we seek  
In kindred art with noblest school compare,  
And give the great Greek architect no less  
Than marble sculptur'd—as of Greek *by Greek*.

"Greek" Thomson was of opinion that sculptors themselves should design the pedestals of their statues—at least roughly, putting them into the hands of architects for detail. Mr. Mossman, however, employed architects, possibly giving them such dimensions as would be in proportion with the respective statues. The Peel pedestal was designed by Thomson, and I believe that both he and Mossman objected to its cope or cornice, but, of course, the committee knew better than the sculptor and the architect. The Livingstone pedestal was designed by Messrs. Campbell Douglas & Sellars, and the pedestals for Campbell and Macleod by Mr. Low.

Till within a comparatively recent time Glasgow took little interest in decorative sculpture. The tympana of some of its noblest porticos—the Royal Exchange, the Royal Bank, and those by "Greek" Thomson—are still empty; and besides the friezes I have mentioned, I remember only those on the Methodist Chapel in Sauchiehall Street and that grand conception and composition by Buchan on the stylobate of the County Buildings, and the frieze on the old Merchants' House by the same artist. The sculptures (by Handyside Ritchie, I think) of the small pediments in the Commercial Bank are worthy of that noble building; there are also sculptures, various, on the Municipal Buildings that are at least equal in value to the architecture.

We appreciate underground railways and such railway bridges as span the river; these are understandable, and yield dividends; and our buildings are neither better nor worse for the utilitarian purposes for which they are built, whether they have cut upon them allegorical or historic friezes, or whether they have not. We like our art within our walls, for private, not public delectation, the realistic picture that needs not to be inscribed "This is a

peacock," or a "primrose," and which we have paid for with our own money, or the bust in idealistic marble in which the artist has done his best to give a sculpturesque effect to our prosaic, commonplace features. As Touchstone says—they may be poor things, but they are *our own*. However, now that we are living a more public life, when everybody's business is everybody else's, or, as St. Paul puts it, "Looking not every man on his own things, but every man also on the things of others"—and with Art, that is to say, Fine Art, here, there, everywhere—we may hope that at least our public buildings may follow those of other times and climes in glyptic embellishment, as well as in copying the proportions of their orders.

Mr. Mossman died, somewhat suddenly, in the Island of Bute, on the 22nd of September, 1890. His body was interred in Sighthill Cemetery, and the funeral was large and representative, embracing members of the Royal Scottish Academy, sculptors, painters, architects—one sculptor coming from Inverness—and many personal friends, some of whom had been long or often associated with him in several of the local art circles. A large number of the workmen from the granite works assembled a little beyond the burial-place that they might see the lowering of the coffin of their lamented chief.

I must say before closing that for several years Mr. Mossman had in his studio the valuable assistance of Mr. Leslie, the sculptor of the bronze statue of Mr. James White, a wealthy manufacturing chemist, and that I am indebted for several of the facts and incidents in this paper, given, however, for another purpose, to Mr. Mossman's worthy friend, Mr Greenlees.

Himself though dead, his works yet speak :  
 Though life is short, yet art is long,  
 Not art that's fever'd, cold, or weak,  
 But art that from its source is strong—  
 The spirit of the grand old Greek,  
 Whose godlike statues temples throng;  
 Such Mossman studied, large and free,  
 Free, yet by sov'reign law restrain'd.  
 "Th' elements so mix'd," agree  
 That art is like to nature feign'd,  
 "Motion and breath left out," yet o'er  
 The glyptic form th' ideal thrown  
 As "light was ne'er on sea or shore,"  
 The spark divine by which there shone  
 The statue's soul.

**Himself in face**

And form a regal presence, where  
Were join'd with dignity the grace  
And carriage fit such stateliness to bear.

As was his art, so free and large

His heart and hand ; how few that knew  
How many needy shar'd the charge

His bounty made ! They were but two—  
Himself and them—of humankind.

From men like him we lessons learn  
In what of hand, and heart, and mind,  
Is best.

—In this I've feebly sought to earn  
For humblest stone a place on Mossman's cairn.

XIX.—*Memoir of the late Professor Dittmar, LL.D., F.R.S.,  
F.R.S.E.* By CHARLES A. FAWSITT, F.R.S.E., F.C.S.

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[Read before the Society, 27th April, 1892.]

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By the death of Professor Dittmar this Society has lost one of the ablest and most distinguished of its members, and, as it is fitting that the work of one so eminent in his profession as a scientific chemist should be placed on record, I was asked to prepare a memoir, seeing that I had been associated with him in some of his work, and also had the pleasure of knowing him in private life. In compiling this memoir, I wish to bear testimony to the fact that in his person one of the most conscientious and indefatigable of scientific workers has passed away from our midst, and that his loss will not only be felt by this Society and by the College in this city with which he was so long connected, but by the chemical world at large—as the name of Dittmar is as well known by scientific men on the Continent as it is in this country. The deceased was an unwearied contributor, not only to the extension of the Science of Chemistry by his able researches, but also by his literary work, and his name will be handed down with much honour to future generations.

The death of Professor Dittmar, on 9th February, 1892, came with painful suddenness to his family, friends, and students; and as the facts, no doubt, are familiar to most of our members, it will suffice just to mention the bare details of the sad event. With the exception of a slight cold, he had been, to all outward appearances, in his usual health and spirits, and the writer, who had had an interview with him shortly before his death, could not detect anything unusual about him; but he felt unwell on the morning of that day, and left his laboratory earlier than usual. As the day wore on he was suddenly taken ill, and he seemed to realise the fact that his condition was serious, as he remarked to his eldest son that he would be dead on the morrow!—which turned out to be too true. He gradually sank into a

hopeless condition, although the best medical advice was procured, and he was carefully tended by his affectionate wife and family. Shortly before midnight he quietly passed away, the immediate cause of death being the rupture of the cerebral arteries, bringing about paralysis of the nerve centre which controls the breathing.

He may be said to have died in harness, and among his last few utterances were instructions regarding his laboratory. Not long previously he and his loving wife celebrated their "silver wedding," surrounded by many friends, and it was remarked that the happy couple looked as if they might celebrate their "golden wedding," but, alas! for human calculations when life and death are concerned, for in six months he had passed over to the majority, at the age of fifty-nine years. And although, in one sense, his life was short, yet, if life were gauged by the amount of work done, he had lived far beyond his years.

In solving chemical problems he cast aside difficulties which to most men would have seemed almost, if not actually, unsurmountable, and he appeared to have been inspired in his constant endeavour to approach more nearly towards that which is perfect and true, and in reaching forth to it with an eager capacity which was only bounded by his physical constitution. He was endowed with the rare faculty of taking pains, and when combined, as it was, with genius, he wielded a power which will leave its imprint on the pages of the history of science.

William Dittmar was born in 1833, in Darmstadt, in Germany—the birthplace also of his friend Dr. Schorlemmer, Professor of Organic Chemistry in the Owens College, Manchester. In early life he showed a decided chemical bent, and was apprenticed to an apothecary (his future brother-in-law) in his native town; but his aspirations were towards something higher, and he gave up the monotony of the drug shop, and entered the laboratory of the renowned Bunsen, at Heidelberg, who quickly discovered the talent which lay undeveloped in his new student, and raised him to the position of assistant. Mr. (now Sir Henry) Roscoe, who was then working as a student with Bunsen, formed a very high opinion of our deceased fellow-member, and persuaded him to accompany him to Manchester, and become his private assistant. It was not long, however, before Sir Henry Roscoe was elected to the Chair of Chemistry in the Owens College, and he retained Professor Dittmar as his assistant. He fulfilled his duties here with much acceptance. After staying a few months at Owens College, he was offered and

accepted the position of chief assistant to Sir Lyon Playfair, at the University of Edinburgh, where he remained eight years. His enthusiasm for his work had its natural effect upon all his students, who profited much by his teaching.

It was during this period that he married the sister of his first employer, and a wise step it proved to be, as in his wife he had a partner who sustained him by sweet counsel and sound advice during the years when he had many difficulties to face; and it was a pleasure for him in after years to speak of her devotion and sagacity.

It was in the Edinburgh laboratory that he first made the acquaintance of Professor Dewar, with whom a friendship was formed which long continued to ripen; and his former student, I am told, always regarded him as one of the greatest laboratory teachers in this country, if not, indeed, the very greatest of them, and this opinion is endorsed by many other persons.

In 1869 he was persuaded to return to his native country as a tutor, and for three years he devoted his time to private teaching, lecturing on meteorology, and studying. He felt, however, that the work was not congenial to his tastes, and he was very pleased to get the offer of the post of assistant to Professor Crum Brown in the University of Edinburgh, which he gladly accepted, as he felt he was returning to old friends. The friendship which he here formed with Professor Crum Brown was one of mutual affection, and up to his death he often sought his valuable advice, looking up to him as a scientific man of extraordinary ability. His stay at Edinburgh was short, for, after remaining a year, he accepted the post of chief assistant to Sir Henry Roscoe, at the Owens College; but before he had been little more than installed in his duties, the Chair of Chemistry in what was then called the Andersonian University fell vacant, through the acceptance by Professor Thorpe of the Chemical Chair at the Yorkshire College, Leeds. Professor Dittmar was an applicant for the vacancy, and the directors elected him.

The choice was a very fortunate one for the "Andersonian," as after events proved. Although he had many difficulties to face at the outset, he felt within himself the power to work it up to something like the position which it had enjoyed under the most successful of his predecessors. When he succeeded Professor Thorpe, the institution was called a "University," and the specific duties were analogous to those of the Professors of Chemistry

at the Universities of Edinburgh and Glasgow. There was attached to it the "Freeland" lectureship, which consisted of an evening course of lectures, specially for the benefit of persons occupied in works of various kinds, warehouses, &c., who were prevented from attending the day lectures.

The labours of the few following years were very arduous and anxious, and it shows very well the calibre of Professor Dittmar when it is mentioned that on his entering his duties at the "Andersonian" his chair was unendowed, and his laboratory unfurnished, and yet, with little or no capital, he gradually equipped his laboratory until—I may say, without fear of contradiction—there was no other in the kingdom which offered such advantages to students in the matter of apparatus; and the result was, as it deserved to be, an unqualified success. The students, whose number at first was small, gradually increased, until he had, on two occasions, to apply to the college authorities for more accommodation, which was gladly conceded. The laboratory daily attendance of students at one time reached sixty-three in number. His fame as a teacher reached even to foreign lands, for students came to him from all parts of the world. He often said that it was his ambition to raise his chair to a high level of excellence, and he felt justly proud when he saw that it was fulfilling his expectations.

It may be asked what Professor Dittmar's special qualities were which attracted students: and, first of all, it was that he excelled as a laboratory teacher, and that, by much personal contact with his students, he infused into them some of his own enthusiasm, earnestness, and love for work. His abhorrence of anything slipshod was very marked, and unless a student endeavoured, so to speak, to become part of himself, there was little in common between them. His hold upon his students was remarkable. They not only respected him for his abilities, but they learned to love him for his kindness, unselfishness, and scientific accuracy.

It was not only as a teacher, however, that he shone conspicuously: as an investigator he took front rank; as a designer of apparatus he was well known, especially in the construction of chemical balances, which was quite a hobby with him; he was looked up to as the greatest authority of his time on such matters, and the improvements which he suggested have been applied by the best balance makers both in this country and in Germany. His apparatus for gas analysis affords another good example of

his inventive capacity. His knowledge of mathematics enabled him to go more deeply into scientific problems than many who were less liberally endowed, and it is well known that he would have shone as a professor of mathematics. The trouble which he took in working up his different formulæ to agree with his experimental data was astonishing. I had the privilege of going through several of such series of calculations with him. What would have satisfied most men would not pass with him, and, when engaged in his calculations, a free use of the "method of the least squares" was never considered troublesome when anything like a nearer approach to accuracy could be obtained.

His evenings were principally occupied in writing, and it is a question whether his physical frame was equal to the demands put upon it, as the literary work seemed to tell upon him, although his love for it would not allow of his feeling, or, at any rate, confessing, that it was really the case. He was an inveterate smoker, and it was only a few years since, when he was taken unwell, that his medical adviser persuaded him to give up smoking, as he could see that it had had a more or less serious effect on his health. It was after his recovery that, accompanied by a friend, he visited Italy, Egypt, and the Holy Land, and came back quite restored. He was loud in his praises of ancient Egypt and Italy, but he could not be persuaded to say a good word for the Holy Land. The amount of literary work which he got through was very considerable, and if he had encouraged it he could have had as many appointments as would have filled up all his time. He was a regular contributor to the *Encyclopædia Britannica*, and also wrote special articles for the *National Encyclopædia*, *Watt's Dictionary*, *Thorpe's Applied Chemistry*, and several German publications. Prominent among his twenty-eight articles in the *Encyclopædia Britannica* were those on "Fermentation," "Metals," "Sea Water," "Prussic Acid," "Platinum," "Phosphorus," "Distillation," "Nitrogen," "Lead," "Mercury," "Metallurgy," "Zinc," and "Sulphur"; in *Watt's Dictionary*, "Analysis"; in the *National Encyclopædia*, "Atoms"; and in *Thorpe's Applied Chemistry*, "Cyanides" and "Balances." These articles were all masterly productions, and characterised by that thoroughness which pervaded all his work.

The books which he published are important contributions to chemical literature, and have supplied a want long felt by the more advanced student and analyst. His first works were a

"Manual on Qualitative Analysis," for more advanced students, and a smaller book on the same subject for elementary work, more especially for medical students. Next came his "Tables to facilitate Chemical Calculations," which, if properly used, are a great help in more advanced laboratory work. Then followed "Quantitative Chemical Analysis," including "Gas Analysis," which embodies much of his laboratory experience, and through it can be traced the master hand seeking to narrow everything down to its simplest and truest form. His latest publication was "Chemical Arithmetic," which is a valuable book embodying logarithm tables, and is admirably suited to the requirements of students. All his works are of outstanding merit, and will increase his reputation.

I had almost omitted to speak of Professor Dittmar as a lecturer, in which capacity his freshness of thought and keen insight into the fundamental theories upon which the science of chemistry is built were very refreshing. His lectures were not a mere compilation; and although he treated the same subject session after session, there was always in his treatment something new to relieve what otherwise would have been mere drudgery to himself.

His research work is embodied in a large number of papers, the chief of which were read before the Royal Society of Edinburgh. Perhaps the work of the greatest importance was his report, consisting of 240 large folio pages, on the samples of sea water sent to him by the "Challenger Expedition" Committee for analysis. This work occupied several years, and he spent in it an amount of thought, ingenuity, and close application, which can only be partly realised by going through the printed volume, as the work which was entailed in the preliminary analysis, trials, and testing of apparatus, especially in the analysis and estimation of the gases absorbed in the waters, would have filled a far larger volume. This piece of work alone would have been of sufficient merit to hand down his name as a great chemist, but it was only a small portion of it, which, I may say, was mostly all done whilst in Glasgow. Two important researches were published, in conjunction with Sir Henry Roscoe, whilst in the Owens College, and they have, perhaps, been of the most practical value, and were so looked upon by Professor Dittmar himself; they were entitled "The Absorption of Hydrochloric Acid Gas by Water," and "The Absorption of Ammonia Gas by Water," and his results have received since much valuable confirmation in practice.

The research, in conjunction with Mr. Henderson, on the "Gravimetric Composition of Water," which was communicated to this Society last session, will be fresh in the minds of members. As a critical piece of work it would be difficult to surpass. Although his results confirmed those of other investigators, he was instrumental in pointing out grievous errors which had been committed by even such eminent chemists as Dumas, and Erdmann, and Marchand. This research received the award of the "Graham Medal," which was a well-merited tribute to the author's ability, and to his disposition to grope after scientific accuracy.

Professor Dittmar had a great desire to test the standard numbers upon which chemical science is built, and his "Determination of the Atomic Weight of Platinum," in conjunction with Mr. M'Arthur, was another example of his research in this direction.

It is gratifying to be able to state that his merit was recognised by those bodies which had honours to bestow. He was elected a Fellow of the Royal Societies of London and Edinburgh, and LL.D. of the University of Edinburgh. The award of these honours will give some indication of the repute in which he was held as a man of science. He was a juror in the Edinburgh and Glasgow Exhibitions, and his articles, which appeared in the *Glasgow Herald*, on the chemical exhibits in the latter were highly spoken of.

He had a kindly and generous disposition, and many a poor person has blessed him for his liberality. He was keenly sensitive, and held strong convictions, which he was not slow in expressing, as he looked upon that as part of his duty, even if he suffered in consequence. His private life was a happy one, surrounded, as he was, by the most loving, thoughtful, and attentive of wives, and by children whose delight was to please and obey him. His sons have inherited their father's common-sense, and promise to hand down the name "Dittmar" with honour. As a friend he was cheerful and eminently sympathetic, and not insensible to the charms of light humour. He delighted to make others happy, and was ever ready to help and encourage, even at great personal self-denial, young men who wished to pursue science as a calling and many a one who has come to him not knowing how to pay his way has found his bill reduced to a merely nominal sum, or cancelled altogether. To sum up, Professor Dittmar was in every

sense a true man—true to his family, his friends, and his profession. As a chemist he has had few superiors, and his name will doubtless be revered by future generations of scientific men, as it is by the present one.

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## LIST OF DITTMAR'S RESEARCHES.

- 1859. Absorption of Hydrochloric Acid Gas by Water. (Roscoe and Dittmar.)
- 1859. Absorption of Ammonia Gas by Water. (Roscoe and Dittmar.)
- 1860. Water Bath with Constant Level.
- 1869. Dissociation of Liquid Sulphuric Acid.
- 1869. Ethylic Carbonate from Ethylic Ether. (Dittmar and Cranston.)
- 1870. Oxymethylphenylformic Acid from Toluic Acid.
- 1872. Oxymethylphenylformic Acid.
- 1873. Vapour Density of Potassium. (Dittmar and Dewar.)
- 1875. Formulæ for Gases.
- 1876. Gas Governor.
- 1876. Precision Balance.
- 1876. Coal Gas.
- 1876. Allyl, Ethyl, and Methyl Alcohols. (Dittmar and Stewart.)
- 1877. Note on Reboul's Normal Pyrotartaric Acid.
- 1877. Determination of Chromium in Chrome Ores.
- 1877. Determination of Organic Matter in Water. (Dittmar and Robinson.)
- 1881. Differential Method of Specific Gravity Determination.
- 1884. Nickel Alkali-proof Vessels.
- 1888. Instability of Double Sulphates of Magnesium.
- 1888. Atomic Weight of Platinum. (Dittmar and M'Arthur.)
- 1888. Physical Properties of Methyl-Alcohol. (Dittmar and Fawsitt.)
- 1889. Behaviour of Carbonates and Hydrates of the Alkali Metals at High Temperatures.
- 1889. Properties of Lithia and Atomic Weight of Lithium.
- 1890. Gravimetric Composition of Water. (Dittmar and Henderson.)

## REPORTS OF SECTIONS.

SESSION 1891-92.

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[Received at Meeting of Society, 27th April, 1892.]

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### 1. REPORT OF THE ARCHITECTURAL SECTION.

During the Session seven Meetings were held, at which the following papers were read:—

*Monday, 16th November, 1891.*—Opening Meeting, when Mr. James Thomson, President, delivered his Presidential Address.

*Monday, 30th November, 1891.*—Mr. John M'Math, Glasgow School Board, read a paper on "The Progress in School Buildings in Glasgow since 1873."

*Monday, 14th December, 1891.*—Mr. Alexander M'Ara read a paper on "Limes and Cements" (with experimental tests).

*Monday, 18th January, 1892.*—Mr. J. D. Sutcliffe read a paper on "Warming and Ventilation of Public Buildings, with or without Motive Power, with special reference to the American Smead System."

*Monday, 1st February, 1892.*—Mr. William Key, engineer, read a paper on "House Warming and Ventilating, with special reference to Smoke Prevention."

*Monday, 29th February, 1892.* Mr. William Scott Morton, decorator, read a paper on "Colour."

*Monday, 14th March, 1892.*—Mr. Thos. Gildard, architect, read a paper on "A Notice of John Mossman, H.R.S.A."

The thanks of the Section are due to those gentlemen.

At the Annual Business Meeting held on Monday, 14th March, 1892, the gentlemen named on p. 334 were elected to office for the ensuing year.

A. LINDSAY MILLER, Architect,  
121 WEST REGENT STREET,  
*Hon. Secy.*

**2. REPORT OF THE GEOGRAPHICAL AND ETHNOLOGICAL SECTION.**

No papers have been read from this Section during this Session; but five Meetings have been held under the joint arrangement with the Royal Scottish Geographical Society, when lectures were delivered by the following gentlemen:—Lord Lamington, Mr. Graham Kerr, Mr. A. J. Mounteney Jephson, Professor O. G. Knott, and Mr. H. M. Cadell. All the lectures were illustrated by lime-light views.

GEO. A. TURNER, M.D.,  
*Secretary.*

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**3. BIOLOGICAL SECTION.****4. CHEMICAL SECTION.**

Both of these Sections are for the present suspended by Vote of Council, 26th November, 1890.

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**5. REPORT OF THE ECONOMIC SCIENCE SECTION.**

During the Session 1891-92 four papers were read at Sectional Meetings, or as communications from the Section to the Society—namely, as follow:—

“Women’s Wages,” by Mr. William Smart, M.A.; 9th December, 1891.

“The School of Le Play,” by Professor Patrick Geddes; 6th January, 1892.

“The Call for Currency Reform, and Mr. Goschen’s Response,” by Mr. George Handasyde Dick and Professor James Mavor; 12th February, 1892.

“A Legal Eight-Hours’ Day,” by Mr. H. De Mattos, B.A.; 29th February, 1892.

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**6. REPORT OF THE MATHEMATICAL AND PHYSICAL SECTION.**

There are no Associates of this Section, and hence there was no meeting during the Session; but several papers obtained through it were read at the ordinary meetings of the Society, and will be printed in the *Proceedings*.

MAGNUS MACLEAN,  
*Secretary.*

7. REPORT OF THE SANITARY AND SOCIAL ECONOMY SECTION.

A Meeting of the Section was held on 11th November, 1891, at which the Office-Bearers for the year were elected.

It is a matter of regret that it has been found impossible to follow up this year the subject of "The Hygiene of Schools" begun last Session, but the gentlemen from whom communications were expected were unable, from want of time, to prepare their papers.

The following papers were read during the Session before the Society on behalf of this Section:—Dr. Eben. Duncan, on "Tuberculosis;" Dr. W. Ernest F. Thomson, on "Fogs."

W. R. M. CHURCH, C.A.,  
*Hon. Secy.*

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8. REPORT OF THE PHILOLOGICAL SECTION.

Two papers were read before the Society as contributions from the Section, namely:—

Professor Tille's, on "The Origin of the Faust Legend;" and Dr. Colville's, on "Rural Scotland in the Time of Burns," illustrated by lime-light transparencies.

Three other papers were promised, but could not be got ready in time. They are held over for next Session.

At the Annual Business Meeting of the Section, 10th November, 1891, Rev. Professor Robertson was elected President in room of Professor Jebb, resigned; Dr. Ross a Vice-President; and Professor Bradley a Member of Council.

JAMES COLVILLE, D.Sc.,  
*Hon. Sec. and Treas.*

## MINUTES OF SESSION.

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*4th November, 1891.*

The Philosophical Society of Glasgow held its First Meeting for Session 1891-92 on the Evening of Wednesday, 4th November, 1891, at Eight o'Clock, in the Society's Rooms, 207 Bath Street—Dr. J. T. Bottomley, F.R.S., Vice-President, in the Chair.

1. The Minutes of Meeting held on 29th April, 1891, which had been printed in Vol. XXII. of the Society's *Proceedings*, were held as read, were approved of, and signed by the Chairman, who announced that the President was confined to bed through illness.

2. The Opening Address of the Session by Dr. J. G. M'Kendrick, F.R.S., President, on "Human Muscle as a Transformer of Energy," was read by Dr. J. M'Gregor Robertson, M.A. Dr. Joseph Coats moved a hearty vote of thanks to the President for the Address, and took occasion to make some remarks upon it. Mr. H. A. Mavor, Mr. Alexander Scott, and the Chairman also made some remarks. Dr. M'Gregor Robertson replied, and was also awarded the thanks of the Meeting.

3. Mr. David Stewart and Mr. William Bottomley were appointed to audit the Treasurer's Accounts for the year 1890-91.

4. The following Candidates for admission to the Society were duly elected:—Mr. Ventura de Callejon Carstens, 7 Woodlands Terrace, Glasgow; Mr. George Thorne, jun., Commission Agent, 1 Annfield Terrace West, Partick, Glasgow; and Mr. T. F. Barbour, The Technical School, Coatbridge.

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*18th November, 1891.*

The Annual General Meeting of the Philosophical Society of Glasgow was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 18th November, 1891, at Eight o'Clock—Dr. J. G. M'Kendrick, F.R.S., President, in the Chair.

1. The Minutes of the First Ordinary General Meeting for Session 1890-91, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following gentlemen elected on 4th November were admitted to the Membership of the Society:—Mr. Ventura de Callejon Carstens, Mr. George Thorne, jun., and Mr. T. F. Barbour.

3. The Annual Report by the Council on the State of the Society having been printed in the Billet convening the Meeting, was held as read. Its adoption was moved from the Chair, and unanimously agreed to. The Report is subjoined:—

#### REPORT OF COUNCIL FOR SESSION 1890-91.

I. *Meetings*.—During the Session to which this Report refers, and which began on 5th November, 1890, and closed on 29th April, 1891, thirteen meetings of the Society were held—all in the Society's Rooms. At those meetings twenty-eight communications were made to the Society, on a great variety of subjects, and almost the whole of them have been published *in extenso* in Vol. XXII., of the Society's *Proceedings*.

II. *Membership*.—At the beginning of the Session there were 647 Ordinary Members on the Roll. In the course of the Session 41 candidates were elected to the Membership, and from the "Suspense List" 3 Members were reinstated, making 691. Of these, 25 have resigned, 12 have died, 3 have left Glasgow, and their names have been placed on the "Suspense List," and 9 have been struck off the Roll for non-payment of subscriptions, so that at the beginning of Session 1891-92, there were 642 Members, being a decrease of 5. Of the New Members admitted during the Session, 4 qualified themselves as Life Members. There are now 113 Members of that class. In the List of Honorary Members, the number of whom is limited to 20, there are 3 vacancies existing, so that the Roll now includes 17 Honorary Members, 5 being Continental, 3 American or Colonial, and 9 British. The number of Corresponding Members remains at 10, as it was a year ago. The Membership of the Society, then, is as follows:—Honorary Members, 17; Corresponding Members, 10; Ordinary Members (Annual and Life), 642; or a total of 669.

III. *Sections*.—(1) The *Architectural Section* held eight meetings during the Session, at which seven papers were read, in addition to the President's Opening Address. One of the papers is published in full in the *Proceedings*.

(2) Two papers were contributed to the Society from the *Sanitary and Social Economy Section*, one of which is given in full and the other in abstract in the *Proceedings*.

(3) Several papers came before the Society during the Session from or through the *Geographical Section*, and these were read at joint-meetings of the Society with the Glasgow Branch of the Royal Scottish Geographical Society. They are named in detail in Dr. Turner's Report of the Section, on page 317 of the *Proceedings*.

(4) The *Mathematical and Physical Section* provided a number of the Sessional papers that were communicated to the Society, several of which find a place in the *Proceedings*, and are illustrated.

(5) A considerable amount of work was done in the course of the Session by the *Economic Science Section*, and two very valuable papers provided by it were read before large meetings of the Society. They appear in the *Proceedings*.

(6) There were no separate meetings of the *Philological Section* for reading papers during the Session, but two communications which were provided by it were read before the Society, and appear *in extenso* in the *Proceedings*. One of them was given by Professor Max Müller, who was recently elected an Honorary Member of the Society.

IV. *Proceedings, Volume XXII.*—The new Volume of the Society's *Proceedings*, which has already been several times referred to in this Report, contains twenty-four separate communications—addresses, full papers, and abstracts. It contains numerous illustrations embodied in the text, as also three separate full-page plates.

V. *Graham Medal.*—The President of the Society, as the only remaining Member of the Committee originally entrusted with the duty of awarding the Graham Medal as occasion arises, having requested the Council of the Society to take the place of the other Members, and the Council having agreed to do so, and to take action at this time, it has been resolved that it should now be awarded on account of the paper communicated to the Society last Session by Professor Dittmar, the joint-production of himself and Mr. J. B. Henderson, and having as its subject "The Gravimetric Composition of Water." This is regarded as a valuable contribution to Chemical Science, and as being well worthy of the Society of which Graham was formerly a Vice-President.

VI. *Finance.*—The Treasurer's Statement opens with a balance of £190 1s. 8d., and closes with a balance of £257 6s. 1d., being an increase of Funds during the year of £67 4s. 5d. It is believed that all current indebtedness of the Society, up to 31st October, 1891, has been paid.

By order and on behalf of the Council.

(Signed) JOHN MAYER,  
*Secretary.*

4. The Treasurer's audited Statement of the Funds of the Society, which had also been printed in the Billet, was next submitted by the Chairman, and its adoption was unanimously

approved of. The Abstract of Treasurer's Account of the Graham Medul and Lecture Fund, and that of the Science Lectures Associated Fund, were also submitted and approved of. The several Financial Statements are given on pp. 318-321.

5. Mr. John Robertson, on behalf of the Library Committee, submitted the Report on the State of the Library. Its adoption was agreed to, and on the motion of Mr. Robertson, the thanks of the Society were awarded to the donors of Books to the Library during the year. The Report was as follows :—

#### REPORT OF THE LIBRARY COMMITTEE.

During the past year 21 volumes and 17 pamphlets were presented to the Society, 44 volumes and 418 parts were received in exchange for the *Proceedings*, and 46 volumes and 73 parts were purchased.

The periodicals at present received at the Library number 100, of which 75 are bought and 25 presented. Of these, 27 are weekly, 4 are fortnightly, 46 are monthly, and 23 are quarterly.

Exchanges have been effected with 170 Societies and Public Departments, representing the leading scientific institutions in almost all parts of the world.

Altogether, there has been during Session 1890-91 an addition to the Library of 242 volumes, 431 parts, and 17 pamphlets. The number of volumes at present in possession of the Society is estimated to be 11,106.

There has been an increase in the number of readers over that of the previous year; 556 volumes were taken out by 354 members.

Since last Report the following Societies, &c., have been added to the exchange list :—Bureau of Education, Washington; Technological Museum, Sydney; Department of Mines, Sydney; Malacological Society, Brussels; Hong Kong Observatory; Architects' Register; British Museum (Natural History Department); *The Lancet*; and Imperial Academy of German Naturalists.

In Volume XXII. of the *Proceedings*, pp. 345-356, there will be found a list of the additions to the Library by purchase up to June, 1891, the titles of the books presented, with the names of the donors, the names of the Societies and Public Departments with which exchanges are effected, and a list of the periodicals received by the Society.

JOHN ROBERTSON, LIBRARIAN,  
*Convener.*

6. On the motion of the Chairman, the best thanks of the Society were awarded to the Treasurer and the Librarian for their services during the past year.

Dr.

## ABSTRACT OF HONORARY TREASURER'S

AND COMPARISON WITH

	1890-91.	1889-90.
To BALANCE in Bank and Treasurer's hands from last year,	£190 1 8	£65 14 1½
„ SUBSCRIPTIONS to 31st October, 1891—		
39 Entry-moneys at 21s., . . . . .	£40 19 0	55 13 0
Annual Dues at 21s.—		
Arrears, . . . . .	£4 4 0	
For 1890-91, 489 Ordinary		
Members, . . . . .	513 9 0	
„ „ 35 New Members, 36 15 0		
	554 8 0	531 5 0
Life Subscriptions at £10 10s.—		
1 Old Member, . . . . .	£10 10 0	
4 New Members, . . . . .	42 0 0	
	52 10 0	105 0 0
	647 17 0	
„ GENERAL RECEIPTS—		
Bank Interest, . . . . .	£5 3 10	7 17 6
Proceedings sold, . . . . .	0 8 0	0 11 6
	5 11 10	
„ LECTURE ON “ANIMAL LOCOMOTION” by Mr. Eadweard		
Muybridge—		
Tickets sold, . . . . .	0 0 0	47 16 6
„ SCIENCE LECTURE FUND—		
Grants, . . . . .	0 0 0	10 8 3
„ ARCHITECTURAL SECTION—		
83 Associates' fees for 1890-91, at 5s., . . . . .	20 15 0	24 15 0
„ ECONOMIC SCIENCE SECTION—		
31 Associates' fees for 1890-91, at 5s., . . . . .	7 15 0	9 0 0
„ GEOGRAPHICAL AND ETHNOLOGICAL SECTION—		
Associates' fees, . . . . .	8 5 0	0 0 0
„ MATHEMATICAL AND PHYSICAL SECTION—		
Associate's fee, . . . . .	0 0 0	0 5 0
„ PHILOLOGICAL SECTION—		
Associates' fees, . . . . .	0 0 0	1 0 0
	£880 5 6	£879 5 10½

*Memo. by Treasurer.*—The Amount invested by the Society in the Bath Street Joint Buildings up to 31st October, 1891, is, as in last Account, . . . £3,547 8 1½  
 whereof, Paid from Society's Funds, . . . £2,047 8 1½  
 Do. Society's half of £3,000 Bond, . . . 1,500 0 0

£3,547 8 1½

J. M.

ACCOUNT—SESSION 1890-91,  
SESSION 1889-90.

Cr.

	1890-91.	1889-90.
By GENERAL EXPENDITURE to 31st October, 1891—		
Salary to Secretary, . . . . .	£75 0 0	£75 0 0
Allowance for Treasurer's Clerks, . . . . .	15 0 0	15 0 0
	£90 0 0	
New Books & Periodicals, British & Foreign, £111 4 7		106 16 9
Bookbinding, . . . . .	40 0 5	41 10 11
Printing Circulars, <i>Proceedings</i> , &c., . . . . .	155 0 0	141 0 0
Lithographs, Woodcuts, &c., for <i>Proceedings</i> , &c., £10 13s. 3d., less Contribution to cost of		
Illustration, £2, . . . . .	8 13 3	23 19 6
Postage and delivery of Circulars, Letters, &c., 36 3 11		35 6 5½
Stationery, Diplomas, &c., . . . . .	7 11 7	12 7 5
	358 13 9	
Fire Insurance on Library for £5,400, . . . . .	£6 1 3	6 1 3
Postages, &c., per Secretary, £2 18s. 6d.; per Treasurer, £2 5s. 11½d., . . . . .	5 4 5½	5 17 2
	11 5 8½	
Joint Expenses of Rooms—Society's half of £345 5s. 3d., being Interest on Bond, Insurance, Taxes, Cleaning, Repairs, Lighting, and Heating; Salaries of Curator and Assistant, less half of £88 12s. 6d., Revenue from Letting, . . . . .	128 6 4½	138 16 2½
„ LECTURE EXPENSES—		
Scottish Geographical Society, Rent for four Joint Lectures, . . . . .	£4 0 0	
Advertising, Reporting, and Sundries, . . . . .	5 3 3	
	9 3 3	63 6 9
„ SUBSCRIPTIONS TO SOCIETIES—		
Ray Society, 1891, . . . . .	£1 1 0	
Palæontographical Society, 1891, . . . . .	1 1 0	
	2 2 0	2 2 0
„ ARCHITECTURAL SECTION—		
Expenses per Treasurer of Section, . . . . .	9 8 10½	10 13 8½
„ ECONOMIC SCIENCE SECTION—		
Expenses per Treasurer of Section, . . . . .	£7 18 11½	
Printing Account, . . . . .	2 6 3	
	10 5 2½	8 13 1
„ GEOGRAPHICAL AND ETHNOLOGICAL SECTION—		
Expenses per Treasurer of Section, . . . . .	£1 19 9	
Printing Account, . . . . .	1 10 6	
	3 10 3	2 0 0
„ MATHEMATICAL AND PHYSICAL SECTION—		
Expenses per Treasurer of Section, . . . . .	0 0 0	0 0 6
„ PHILOLOGICAL SECTION—		
Expenses per Treasurer of Section, . . . . .	0 0 0	0 1 6
„ SANITARY AND SOCIAL ECONOMY SECTION—		
Expenses per Treasurer of Section, . . . . .	0 5 0	0 6 0
„ BALANCES, viz. :—		
In Clydesdale Bank, . . . . .	£250 3 10	
In Treasurer's hands, . . . . .	7 1 3	
	257 5 1	190 1 8
	£880 5 6	£879 5 10½

GLASGOW, 12th November, 1891.—We, the Auditors appointed by the Society to examine the Treasurer's Accounts for the year 1890-91, have examined the same, of which the above is an Abstract, and have found them correct, the Balances being—in Clydesdale Bank Two Hundred and Fifty Pounds Three Shillings and Tenpence, and in Treasurer's hands Seven Pounds One Shilling and Threepence.

(Signed) DAVID STEWART.  
WM. BOTTOMLEY.

JNO. MANN, C.A., *Honorary Treasurer.*

## GRAHAM MEDAL AND LECTURE FUND.

Dr. ABSTRACT OF TREASURER'S ACCOUNT—SESSION 1890-91. Cr.

CAPITAL AT 1ST NOVEMBER, 1890—		CAPITAL AT 31ST OCT., 1891—	
Glasgow and South-Western Railway		Investment, <i>per contra</i> ,	£250 0 0
Co. 4 % Preference Stock in name of		Die, - - - - -	18 18 0
the Philosophical Society, in Trust,	£250 0 0		£268 18 0
Value of Die at H.M. Mint,	18 18 0	BALANCE, BEING REVENUE—	
Cash in Bank, - - - - -	£268 18 0	In Bank, on Deposit Receipts,	29 0 9
	18 17 10		
REVENUE—			
Dividend, April, 1891, less Tax, -	£4 17 6		
Oct. " - - - - -	4 17 6		
Interest from Bank, - - - - -	0 7 11		
	10 2 11		
	£297 18 9		£297 18 9

GLASGOW, 12th November, 1891.—Examined and found correct.

(Signed) DAVID STEWART.  
WM. BOTTOMLEY.

JNO. MANN, C.A., Treasurer.

# THE SCIENCE LECTURES ASSOCIATION FUND.

Dr. ABSTRACT OF TREASURER'S ACCOUNT—SESSION 1890-91. Cr.

CAPITAL AT 1ST NOVEMBER, 1890—			CAPITAL AT 31ST OCTOBER, 1891—		
£200	Caledonian Railway Company		Investment, <i>per contra</i> , -	-	£244 4 8
4%	Preference Stock, No. 1, in name		In Bank on Deposit Receipt,	-	8 5 4
	of the Philosophical Society, in Trust,				
cost -	-	£244 4 8	BALANCE, BEING REVENUE—		252 10 0
On Deposit Receipt,	-	8 5 4	In Bank, on Deposit Receipts,	-	16 6 5
Revenue of 1889-90, in Bank,	-	8 4 1			
REVENUE—					
Dividend, April, 1891, less Tax,	-	£3 18 0			
" Oct., "	-	3 18 0			
Interest from Bank,	-	0 6 4			
		8 2 4			
		£268 16 5			£268 16 5

GLASGOW, 12th November, 1891.—Examined and found correct.

JNO. MANN, C.A., *Treasurer*.

(Signed) DAVID STEWART.  
WM. BOTTOMLEY.

## 7. The Society then proceeded to the election of Office-Bearers:—

- (1) On the recommendation of the Council, and on the motion of the Chairman, Dr. Charles Gairdner, Union Bank, was elected a Vice-President in succession to Mr. W. Renny Watson.
- (2) On the motion of the Chairman, Messrs. Mann, Robertson, and Mayer were re-elected Treasurer, Librarian, and Secretary, respectively.
- (3) On the motion of Mr. Alexander Scott, the following gentlemen were elected members of Council for the full term of three years:—Mr. Magnus Maclean, M.A., F.R.S.E.; Mr. Eben. Kemp, Dr. Eben. Duncan, and Dr. George A. Turner, in room of Messrs. Fairweather, Smart, Scott, and Gow, whose term of office had expired.
- (4) On the motion of Dr. Turner, the Office-Bearers of the Geographical and Ethnological Section were elected, in accordance with resolution of Society of 11th April, 1883. There were also elected the Office-Bearers of the Sanitary and Social Economy Section, on the motion of Mr. W. P. Buchan; Mathematical and Physical Section, on the motion of Dr. Bottomley; and of the Economic Science Section, on the motion of Mr. W. W. Blackie—according to Resolution of Society of 18th November, 1885, and 2nd February, 1887; and on the motion of Dr. Colville, the List of Office-Bearers of the Philological Section was agreed to. (Lists of Office-Bearers of the Society and of the various Sections will be found on pp. 332-335).

8. The PRESIDENT then made a statement regarding the award of the "Graham" Medal, which was instituted a number of years ago in order to perpetuate the memory of the late Dr. Thomas Graham, Master of the Mint, and a former Vice-President of the Philosophical Society. He (the President) was the only remaining member of the Committee by whom the award fell to be made, but he had taken the Council along with him, and they had jointly agreed that the Medal, in Gold, and struck at the Royal Mint, should be awarded on account of the Paper communicated to the Society last Session, and published in Vol. XXII. of the *Proceedings*, on "The Gravimetric Composition of Water," by Professor William Dittmar and Mr. J. B. Henderson, the last-named gentleman to receive a similar Medal, in Silver, together with a Premium of Books, as an acknowledgment of his share in the work detailed in the Paper. The Gold Medal was then presented to Professor Dittmar, who acknowledged the honour conferred upon him in a few suitable remarks. The Silver Medal and Premium of Books were also presented to that gentleman for transmission to Mr. Henderson, now in Australia.

9. Professor JOHN FERGUSON, M.A., LL.D., F.R.S.E., F.S.A., F.S.A.(Scot.), read a Paper "On the First Edition of the Chemical Writings of Democritus and Synesius (Part III.), containing an account of copies at Göttingen, Paris, and Rome, for which he received the thanks of the Society.

10. The PRESIDENT exhibited and briefly described a New Form of Saccharimeter for quickly estimating Diabetic Sugar (made by Reichart, of Vienna). He was thanked by the Society,

11. Dr. J. T. BOTTOMLEY, M.A., F.R.S., F.R.S.E., F.C.S., exhibited several New Vacuum Tubes, to illustrate some beautiful phenomena of Electrical Discharges. He was cordially thanked for the exhibition of the experiments.

12. The CHAIRMAN announced that the following candidates had all been elected Members of the Society:—Mr. James Stewart, 2 Lawrence Place; Mr. William Adams, Bank Agent, 28 Ashton Terrace, Dowanhill; and Mr. A. Buchanan Miller, Ventilating, &c., Engineer, 13 North Claremont Street, Glasgow.

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*2nd December, 1891.*

The Second Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 2nd December, 1891, at Eight o'Clock—Dr. J. G. M'Kendrick, F.R.S., President in the Chair.

1. The Minutes of the Annual General Meeting, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following gentlemen, elected on 18th November, were admitted to the Membership of the Society:—Mr. James Stewart, Mr. William Adams, and Mr. A. Buchanan Miller.

3. Dr. John Cleland, F.R.S., Professor of Anatomy in the University of Glasgow, delivered a discourse on "How our Bones Grow," which was extensively illustrated by Specimens, Diagrams, and Demonstrations, and by numerous Microscopes (in the Council

Room). Some remarks were made on the subject of the communication by Dr. Coats and the Chairman, after which a hearty vote of thanks was passed to Dr. Cleland.

4. Mr. C. M. Aikman, M.A., B.Sc., Examiner in Chemistry in the University of Glasgow, read a paper on "The Formation of the Nitrate Deposits of Chil ." Mr. Fawsitt spoke briefly on the subject, and Mr. Aikman was awarded the thanks of the Society for his paper.

5. The President announced that the following Candidates had been elected Members of the Society :—Dr. William Core, Barnhill Hospital, Glasgow, and Mr. George Harley, 29 Burnbank Gardens.

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*16th December, 1891.*

The Third Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 16th December, 1891, at Eight o'Clock—Dr. J. T. Bottomley, F.R.S., Vice-President, in the Chair.

1. The Minutes of the Second Ordinary Meeting, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following gentlemen, elected on 2nd December, were admitted to the Membership of the Society :—Dr. William Core and Mr. George Harley.

3. Mr. Henry Brier, Mem.Inst.Mech.E., of the Scotch and Irish Oxygen Company, Glasgow, read a paper on "The Manufacture of Oxygen by Brins' Process, and Compression of Gases in Cylinders, &c.," which was extensively illustrated by specimens of Cylinders, Lantern Views of Furnaces, Compressing Pumps, &c., and by experiments. After answering a number of questions put by members and visitors, the author was awarded a hearty vote of thanks for his communication.

4. The Chairman announced that the following Candidates had been elected Members of the Society :—Mr. Edward E. Prince, B.A., F.L.S., Professor of Zoology in St. Mungo's College, Glasgow

and Mr. Thomas Young, Engineer, Pollok Patents Gold Extracting Company, Glasgow.

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6th January, 1892.

The Fourth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 6th January, 1892, at Eight o'Clock—Dr. James Colville, Member of Council, in the Chair.

1. The Minutes of the Third Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman, who then moved that Mr. George Younger, Vice-President of the Economic Science Section, occupy the Chair for the remainder of the proceedings.

2. The following gentlemen, elected on 16th December, 1891, were admitted to the Membership of the Society :—Professor Edward E. Prince, B.A., F.L.S., and Mr. Thomas Young.

3. Professor Patrick Geddes, University College, Dundee, read a paper on "The French Economic School of Le Play." (*A Communication from the Economic Science Section.*) Remarks were made on the paper by Professor Mavor, Mr. G. H. Dick, and the Chairman, and a hearty vote of thanks was passed to Prof. Geddes, who briefly replied.

4. Mr. T. Rodger, of Dunedin, New Zealand (formerly of Glasgow), exhibited, and briefly described, his Self-Emptying Hopper Waggon and Spreading Plough for Ballasting Railways. (This invention, which has recently been adopted by the Glasgow and South-Western Railway Company, is in extensive use on the New Zealand, Australian, and American Railways.) Much interest was manifested in regard to the invention, and Mr. Rodger was awarded a very cordial vote of thanks.

5. The Chairman announced that the following Candidate had been elected a Member of the Society :—Professor A. Humboldt Sexton, F.C.S., F.R.S.E., Glasgow and West of Scotland Technical College.

*20th January, 1892.*

The Fifth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 20th January, 1892, at Eight o'Clock—Dr. J. G. M'Kendrick, F.R.S., President, in the Chair.

1. The Minutes of the Fourth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following gentleman, elected on 6th January, 1892, was admitted to the Membership of the Society:—Professor A. Humboldt Sexton.

3. Dr. John Young, Professor of Geology in the University of Glasgow, read a Memoir of the late Sir Andrew Ramsay, F.R.S., a former Director-General of the Geological Survey of Great Britain and Ireland, and Honorary Member of the Philosophical Society. On the motion of the President, a cordial vote of thanks was passed to Dr. Young for his Paper.

4. Mr. W. Anderson Smith of Ledaig, Argyleshire, Member of the Scottish Fishery Board, read a paper on "The Scientific Education of the Senses." A discussion followed, in which the speakers were Mr. William Jolly, Mr. J. G. Kerr, Dr. Colville, and the President. The thanks of the Meeting were voted to Mr. Smith, who made a short reply.

5. The Chairman announced that the following Candidates had been elected Members of the Society:—Mr. John Stevenson, colour manufacturer, 12 Victoria Road, Lenzie; Mr. William R. Farquhar, grain merchant, 13 Belhaven Terrace; and Mr. William Brown, banker, 165 West George Street.

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*3rd February, 1892.*

The Sixth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 3rd February,

1892, at Eight o'Clock—Dr. J. G. M'Kendrick, F.R.S., President, in the Chair.

1. The Minutes of the Fifth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following gentlemen, elected on 20th January, were admitted to the Membership of the Society :—Mr. John Stevenson, Mr. William R. Farquhar, and Mr. William Brown.

3. Dr. W. Ernest F. Thomson read a paper on "Our Present Position regarding Fogs," which led to a discussion, in which the speakers were Mr. F. J. Rowan, C.E. ; Dr. Hugh Thomson, Mr. Gilbert Thomson, M.A., C.E. ; Mr. W. Key, Mr. A. G. Moore, M.A., B.Sc. ; Mr. Alexander Scott, Mr. W. R. W. Smith, Mr. George C. Thomson, F.C.S. ; and Mr. W. P. Buchan. At the close a hearty vote of thanks was awarded to Dr. Thomson, who briefly replied to the speakers.

4. The following Candidates were unanimously elected Members of the Society :—Mr. Graham Somerville, writer, Ardenlea, Crosshill ; Mr. John E. Cameron, heating engineer and smith, 115 Bothwell Street ; and Mr. Thomas Murdoch, heating engineer, 115 Bothwell Street.

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*17th February, 1892.*

The Seventh Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 17th February, 1892, at Eight o'Clock—Dr. J. G. M'Kendrick, F.R.S., President, in the Chair, and subsequently Mr. James Thomson, F.R.I.B.A., President of the Architectural Section.

1. The Minutes of the Sixth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The following gentlemen, elected on 3rd February, were admitted to the Membership of the Society :—Mr. Graham Somerville, Mr. John E. Cameron, and Mr. Thomas Murdoch.

3. A paper was read by Professor G. Baldwin Brown, M.A. of the Watson-Gordon Chair of Fine Art, University of Edinburgh, on "Beauty and Utility in Architecture," with Lantern Illustrations. At the close, a cordial vote of thanks was passed to Professor Brown, on the motion of Mr. Campbell Douglas, seconded by Mr. David Thomson, both of whom made some remarks on the paper, as did also the Chairman (Mr. James Thomson). The author of the paper made a brief reply.

4. On the motion of Dr. Eben. Duncan, seconded by Dr. Glaister, the paper by Mr. Gilbert Thomson (announced in the Billet) was held over for a future Meeting.

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*29th February, 1892.*

The Eighth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 29th February, 1892, at Eight o'Clock—Mr. William Smart, M.A., Vice-President of the Economic Science Section, in the Chair, and subsequently Dr. James Colville, Member of Council.

1. The Minutes of the Seventh Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. A paper on "The Legal Eight Hours' Day" was read by Mr. W. S. de Mattos, B.A., Member of the Executive Committee of the Fabian Society, Trustee of the General Railway Workers' Union, and Vice-Chairman of the London Board of Conciliation. (*A Communication from the Economic Science Section.*) Mr. T. S. Cree and Mr. W. P. Buchan made some remarks on the subject of the paper. Mr. De Mattos briefly replied, and was awarded the thanks of the Society.

3. Dr. A. Tille, M.A., Professor of German Language and Literature, Queen Margaret College, read a paper on "The Origin of the Faust Legend." (*A Communication from the Philological Section.*) The author was awarded the thanks of the Society.

4. The Chairman (Dr. Colville) stated that on learning that Dr. Thomas Muir, M.A., F.R.S.E., Mathematical Master of the High School of Glasgow, had accepted of an important educational appointment in Cape Colony, the Council had unanimously agreed to nominate him for election as one of the Honorary Members of the Philosophical Society, in recognition of his eminence as a mathematician and cultivator of other branches of science, and of his valuable services to the Society. He further stated that the nomination by the Council had that evening been confirmed by the Society.

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*16th March, 1892.*

The Ninth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 16th March, 1892, at Eight o'Clock—Dr. J. G. M'Kendrick, F.R.S., President, in the Chair.

1. The Minutes of the Eighth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. The Chairman referred at some length to Dr. Thomas Muir and his connection with the Society, and, following up his election as one of the Honorary Members, he presented him with the Diploma of that rank.

3. Dr. James Colville, M.A., read a paper on "Rural Life in Scotland during the time of Burns," which was extensively illustrated by lantern views. The author was awarded a hearty vote of thanks for his paper.

4. Professor James Blyth, F.R.S.E., made a short communication to the Society on "Recent Ideas on Electric Conduction," which was experimentally illustrated. The best thanks of the Society were voted to Professor Blyth for his interesting communication.

*30th March, 1892.*

The Tenth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 30th March, 1892, at Eight o'Clock—Prof. James Blyth, F.R.S.E., Vice-President, in the Chair.

1. The Minutes of the Ninth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Mr. Gilbert Thomson, M.A., C.E., Lecturer on Sanitary Engineering, Glasgow and West of Scotland Technical College, read a paper on "The Sewage Problem in Villages and Small Towns." A discussion took place, in which the speakers were Mr. Buchan, Mr. Dobson, Sanitary Inspector under the Lanarkshire County Council; and Mr. A. Mechan. Mr. Thomson made a brief reply, and was thanked for his paper.

3. Dr. Eben. Duncan, Physician to the Victoria Infirmary, Examiner in Clinical Medicine in the University of Glasgow, and Vice-President of the Sanitary Association of Scotland, read a paper "On the Causes of the Spread of Pulmonary Consumption and other Tubercular Diseases, and on the means which may be taken to prevent their Dissemination." A brief discussion followed, in which the speakers were Dr. Hugh Thomson, Mr. N. Dunlop, and Mr. Dunlop Brown. A vote of thanks was passed to Dr. Duncan, who briefly replied to the speakers.

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*13th April, 1892.*

The Eleventh Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 13th April, 1892, at Eight o'Clock—Dr. J. G. M'Kendrick, F.R.S., President, in the Chair.

1. The Minutes of the Ninth Ordinary Meeting of the Society, which were printed in the Billet calling the Meeting, were held as read, were approved of, and signed by the Chairman.

2. Dr. Joseph Coats read a paper on "Sleep, Dreams, and Delirium." In the discussion which followed, Dr. Glaister and the Chairman took part. Dr. Coats was awarded a hearty vote of thanks, and briefly replied.

3. Mr. John Brown, B.Sc., C.E., read a paper on "Some Elementary Facts regarding the Foci of Lenses, with special reference to Dallmeyer's New Tele-Photographic Lens." The paper was illustrated by diagrams shown by lime-light, lenses in experimental mountings, and simple calculations. A discussion took place, in which the speakers were the Chairman, Mr. Alexander Scott, and Mr. Fred. Mackenzie, B.Sc., Secretary to the Glasgow Photographic Association. The thanks of the Society were awarded to Mr. Brown, who made a short reply.

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*27th April, 1892.*

The Twelfth Ordinary Meeting of the Philosophical Society of Glasgow, for Session 1891-92, was held in the Society's Rooms, 207 Bath Street, on the Evening of Wednesday, 27th April, 1892, at Eight o'Clock—Dr. James Colville, M.A., in the Chair.

1. The Minutes of Meeting of 13th April were held as read, were approved of, and signed by the Chairman.

2. Mr. Charles A. Fawsitt, F.C.S., F.R.S.E., read "A Memoir of the late Professor Dittmar," for which he received the thanks of the Society.

3. Mr. William Aitken, Assoc.Inst.E.E., Engineer to the National Telephone Company, read a paper on "Telephone Switchboards, being principally a description of the new Telephone Exchange, Glasgow," which was illustrated in a very complete manner by working telephones, &c. After some questions had been asked and replied to, Mr. Aitken was very cordially thanked for his communication and demonstration.

4. The Reports of Sections for Session 1890-91 were presented by the Secretary, and ordered to be printed in the next volume of the *Proceedings*.

The Chairman then adjourned the Society for the summer recess.

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Measures of Positions and Areas of Sun Spots and Faculae on Photographs taken at Greenwich, Dehra Dun, and Melbourne; with the Deduced Heliographic Longitudes and Latitudes, 1878-1881. 4to. London, 1891, . . .	Solar Physics Committee.
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Examples of the Integral Calculus. By James Hann. 8vo. London, 1850, . . . . .	"
Examples and Solutions of the Differential Calculus. By James Haddon. 8vo. London, 1851, . . . . .	"
A Rudimentary Treatise on Logarithms. By Henry Law. 8vo. London, 1851, . . . .	"
A Rudimentary Treatise on the Integral Calculus. By H. Cox. 8vo. London, 1852, . . .	"
Physical Optics explained according to Mechanical Science. By Thomas Exley. 8vo. London, 1834, . . . . .	"
Euclid's Elements: the first six, and the eleventh and twelfth books. 5th Edition. By J. R. Young. 12mo. London, 1844, . . . .	"

DONATIONS.	PRESENTED BY
Chambers's Mathematical Papers. 8vo. London and Edinburgh, 1874, . . . . .	Dr. Muir.
Exercises on Mechanics and Natural Philosophy. By Thomas Tate. 8vo. London, 1851, . . . . .	„
An Introduction to the Differential and Integral Calculus. 2nd Edition. By James Thomson, LL.D. 8vo., London, 1849, . . . . .	„
A Treatise on Mechanics, applied to the Arts, including Statics and Hydrostatics. 3rd Edition. By H. Mosley. 8vo. London, 1847, . . . . .	„
An Elementary Treatise on Conic Sections and Algebraic Geometry. By G. H. Puckle. 8vo. Cambridge, 1854, . . . . .	„
Algebra: being a Complete and Easy Introduction to Analytical Science. By Philip Kelland. 8vo. Edinburgh. No date, . . . . .	„
The Principles of Mechanics: designed for the use of Students in the University. 4th Edition. By James Wood. 8vo. Cambridge, 1809, . . . . .	„
A Treatise on Conic Sections. 3rd Edition. By Geo. Salmon. 8vo. London, 1855, . . . . .	„
Lunar and Horary Tables. 18th Edition. By David Thomson. 8vo. London, 1839, . . . . .	„
Physical Astronomy, Sound, and Light. By Sir John F. W. Herschel. 4to. No place nor date, . . . . .	„
Farmyard Manure: its Nature, Composition, and Treatment. By C. M. Aikman. 12mo. London, 1892, . . . . .	The Author.
The Nitrate Fields of Chile. By C. M. Aikman. Pamphlet. 1892, . . . . .	The Author.
Extracts from the Records of the Royal Burgh of Stirling, 1519 to 1752. 2 Vols. 4to. Glasgow, 1887, 1889, . . . . .	Sir M. Connal.
Annual Report of the County Council of Stirling for 1891. By John C. M'Vail, M.D. 8vo. Glasgow, 1892, . . . . .	The Author.
A Description of a Machine for Finding the Numerical Roots of Equations. By F. Bashforth. Pamphlet. 1892, . . . . .	The Author.
Bibliography of the Algonquian Languages. By J. C. Pilling. 8vo. Washington, 1891, . . . . .	Smithsonian Institution.
Contributions to North American Ethnology, Vol. I. Parts 1. and 2., and Vol. VI. 4to. Washington, 1890, . . . . .	U. S. Government.
An Appeal to the Canadian Institute on the Rectification of Parliament. By Sandford Fleming. Pamphlet. 1892, . . . . .	Canadian Institute.

DONATIONS.		PRESENTED BY	
Greenwich Observations, 1889, . . . . .		Astronomer Royal.	
Greenwich Astronomical Observations, 1889, . .		„	
Greenwich Magnetical and Meteorological Observations, 1889, . . . . .		„	
Memorial of Joseph Lovering. Pamphlet.		American Academy of	
1892, . . . . .		Arts and Sciences.	

BOOKS PURCHASED 1891-92.

- Hazell's Annual for 1892.
- The Collected Mathematical Papers of Arthur Cayley. Vol. 4. 1891.
- Dictionary of National Biography. Vols. 28, 29, 30, and 31.
- A Treatise on the Mathematical Theory of the Motion of Fluids. By Horace Lamb. 8vo. Cambridge, 1879.
- An Elementary Treatise on Hydrodynamics and Sound. By A. B. Basset. 8vo. Cambridge, 1890.
- Sanity and Insanity. By Charles Mercier. 8vo. London, 1890.
- Evolution of Marriage and of the Family. By Ch. Letourneau. 8vo. London, 1891.
- The Criminal. By Havelock Ellis. 8vo. London, 1891.
- Vorlesungen über Geschichte der Mathematik. By Moritz Cantor. Zweiter Band. 8vo. Leipzig, 1892.
- D'Augustin Cauchy. Œuvres Complètes. Vol. VII.
- Palæontographical Society's Publications :—
- Jurassic Gasteropoda. Part I. No. 5. By W. Hudleston. 4 Plates.
- Inferior Oolite Ammonites of the British Isles. Part 6. By S. S. Buckman. 12 Plates.
- The Devonian Fauna of the South of England. Part 4. By G. F. Whidborne. 17 Plates.
- A Vertebrate Fauna of the Orkney Islands. By Thomas E. Buckley and J. A. Harvie-Brown. 8vo. Edinburgh, 1891.
- Labour and Life of the People. 3 vols. 3rd Edition. By Charles Booth. 8vo. London, 1891.
- Dictionary of Political Economy. Parts 1, 2, and 3. 8vo. London, 1891-2.
- Dictionary of Applied Chemistry. Vol. 2. By T. E. Thorpe. 8vo. London, 1891.
- Star Groups: A Student's Guide to the Constellations, By G. E. Gore. Small 4to. London, 1891.
- The American Commonwealth. 2 vols. 2nd Edition. By James Bryce, M.P. 8vo. London, 1889.
- The Cause of an Ice Age. By Sir Robert Ball. 8vo. London, 1891.
- History of England in the Eighteenth Century. 2 vols. By W. E. H. Lecky. 8vo. London, 1892.
- New Fragments. By John Tyndall. 8vo. London, 1892.
- The Microscope and its Revelations. 7th Edition. By W. B. Carpenter. 8vo. London, 1891.
- The Optics of Photography and Photographic Lenses. By J. T. Taylor. 8vo. London, 1892.

- Das Marokkanische Atlasgebirge. (Erganzungsheft No. 103 zu Petermanns Mitteilungen.)
- L'Année Scientifique et Industrielle for 1891. By Louis Figuier. 12mo. Paris, 1892.
- The Statesman's Year Book for 1892.
- Practical Photo-Micrography by the latest methods. By A. Pringle. 8vo. New York, 1890.
- Coloured Figures of the Birds of the British Islands. 2nd Edition. Parts 1. to 11. By Lord Lilford.
- Transactions of the Royal Society. Vol. 182. 1891.
- Travels amongst the Great Andes of the Equator. 2 vols. By Edward Whymper. 8vo. London, 1892.
- La Nature. Parts 1 and 2. 1891.
- A Treatise on Chemistry Vol. III. Part 6. By Roscoe and Schorlemmer.
- Journal of the Iron and Steel Institute. Vols. 1 and 2 for 1891.
- Die Bevölkerung der Erde. Ergänzungsheft No. 101 zu Petermanns Mitteilungen. 1891.
- Principles of Economics. By Alfred Marshall. 2nd Edition. Vol. 1. 8vo. London, 1891.
- Repertorium der Technischen Journal-Litteratur. 1890 and 1891.
- Murray's New English Dictionary. Part 6. 1891.
- The Meteoritic Hypothesis. By J. N. Lockyer. 8vo. London, 1890.
- Money. By F. A. Walker. 8vo. London, 1888.
- Political Economy. By F. A. Walker. 8vo. London, 1888.
- The Wages Question. By F. A. Walker. 8vo. London, 1891.
- Round the Calendar in Portugal. By Oswald Crawford. 8vo. London, 1890.
- The System of the Stars. By Agnes M. Clerke. 8vo. London, 1890.
- The Theory of Political Economy. By W. Stanley Jevons. 3rd Edition. 8vo. London, 1888.
- Optical Projection: a Treatise on the Use of the Lantern. By Lewis Wright. 12mo. London, 1891.
- Die Adamsbrücke und die Korallenriffe der Palkstrasse. Von Johannes Walther. Supplement 102 zu Petermanns Mitteilungen. 1891.
- Scientific Papers of Thomas Andrews; with a Memoir by P. G. Tait and A. Crum Brown. 8vo. London, 1889.
- Electricity and Magnetism. By A. Guillemin. Translated and Edited by Silvanus P. Thompson. 8vo. London, 1891.
- Dictionary of the Spanish and English Languages. By M. Velazquez. 8vo. London. No date.
- Dictionary of the Italian and English Languages, based upon that of Baretta. Compiled by John Davenport and Guglielmo Comelati. 2 vols. 8vo. London. No date.
- Unconscious Memory. By Samuel Butler. 8vo. London, 1891.
- Jacobi's Gesammelte Werke. Vol. 7.
- Kermarsch and Heeren's Technisches Wörterbuch. Vol. 11, Part 1. 8vo. Prag., 1891.
- A Guide Book to Books. Edited by E. B. Sargant and B. Whishaw. 8vo. London, 1891.

- The First Crossing of Greenland. By F. Nansen. Translated by H. M. Gepp. 8vo. London, 1892.
- Essays on Literature and Philosophy. 2 Vols. By Edward Caird. 8vo. Glasgow, 1892.
- Edinburgh Sketches and Memories. By David Masson. 8vo. London, 1892.
- The Fine Arts. By G. Baldwin Brown. 8vo. London, 1891.
- The Naturalist in La Plata. By W. H. Hudson. 8vo. London, 1892.
- Jahres-Bericht über die Leistungen der Chemischen Technologie. 1891.
- Backward Glances; or, Some Personal Recollections. By James Hedderwick. 8vo. Edinburgh, 1891.
- Jahrbuch über die Fortschritte der Mathematik. Vol. 21. Part 2. 8vo. Berlin, 1892.
- Association Française pour l'Avancement des Sciences. 2 vols. for 1891.
- The Elements of Politics. By Henry Sidgwick. 8vo. London, 1891.
- Vorlesungen über Geschichte der Mathematik. Vol. 2, Part 2. 8vo. Leipzig, 1892.
- Œuvres de Lagrange. Tome Quatorzième et Dernier. 8vo. Paris, 1892.

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THE PHILOSOPHICAL SOCIETY EXCHANGES WITH THE  
FOLLOWING SOCIETIES, &c. :—

AUSTRALIA.

Brisbane—

Royal Geographical Society of Australasia (Queensland Branch).

Melbourne—

Royal Observatory Library.

Patent Office.

Royal Society of Victoria.

Sydney—

Department of Mines.

Royal Geographical Society of Australasia (New South Wales Branch).

Royal Society of New South Wales.

Technological Museum.

BELGIUM.

Brussels—

Académie Royale des Sciences.

Observatoire Royale.

Société Malacologique de Belgique.

Liège—

Société Royale des Sciences.

CANADA.

Halifax—

Nova Scotian Institute of Natural Science.

Hamilton (Ont.)—

Hamilton Association.

London (Ont.)—

Entomological Society of Ontario.

CANADA—*continued.*

## Montreal—

- Canadian Society of Civil Engineers.
- Geological and Natural History Survey of Canada.
- Royal Society of Canada.

## Quebec—

- Literary and Historical Society.

## Toronto—

- Canadian Institute.

## Winnipeg—

- Manitoba Historical and Scientific Society.

## CHILL.

## Santiago—

- Sociedad Científica Alemana.

## CHINA.

## Hong Kong—

- Hong Kong Observatory.

## ENGLAND AND WALES.

## Barnsley—

- Midland Institute of Mining, Civil, and Mechanical Engineers.

## Bath—

- Bath Natural History and Antiquarian Field Club.

## Berwick—

- Berwickshire Naturalists' Field Club.

## Birkenhead—

- Birkenhead Literary and Scientific Society.

## Birmingham—

- Philosophical Society.

## Bristol—

- Bristol Naturalists' Society.

## Cambridge—

- Philosophical Society.
- University Library.

## Cardiff—

- Cardiff Naturalists' Society.

## Essex—

- Essex Field Club.

## Falmouth—

- Royal Cornwall Polytechnic Society.

## Folkestone—

- Folkestone Natural History Society.

## Greenwich—

- Royal Observatory.

## Leeds—

- Leeds Philosophical and Literary Society.

ENGLAND AND WALES—*continued.*

Leicester—

Leicester Literary and Philosophical Society.

Liverpool—

Geological Society.

Historic Society of Lancashire and Cheshire.

Literary and Philosophical Society.

Liverpool Engineering Society.

Liverpool Naturalists' Field Club.

London—

Anthropological Institute.

Architects' Register.

British Museum.

British Museum (Nat. His.).

London—

Chemical Society.

Institution of Civil Engineers.

Institution of Mechanical Engineers.

Junior Engineering Society.

Middlesex Hospital.

Patent Office Library.

Pharmaceutical Society.

Photographic Society.

Physical Society of London.

Royal Geographical Society.

Royal Institute of British Architects.

Royal Institution of Great Britain.

Royal Meteorological Society.

Royal Society.

Royal Statistical Society.

Society of Arts.

Society of Biblical Archæology.

Society of Engineers.

Society of Psychical Research.

*The Lancet.*

Manchester—

Manchester Association of Engineers.

Geographical Society.

Literary and Philosophical Society of Manchester.

*Industries.*

Middlesborough—

Cleveland Institution of Engineers.

Newcastle-upon-Tyne—

North-East Coast Institution of Engineers and Shipbuilders.

North of England Institute of Mining and Mechanical Engineers.

Society of Chemical Industry.

ENGLAND AND WALES—*continued.*

## Swansea—

South Wales Institute of Engineers.

## Truro—

Royal Institution of Cornwall.

## Watford—

Hertfordshire Natural History Society and Field Club.

## Welshpool—

Powys Land Club.

## FRANCE.

## Bordeaux—

Société des Sciences Physiques et Naturelles.

## Paris—

École Polytechnique.

Observatoire Météorologique Central de Montsouris.

## GERMANY.

## Berlin—

Deutsche Chemische Gesellschaft.

Deutscher Kolonial Verein.

Königlich Preussische Akademie der Wissenschaften.

## Bremen—

Geographische Gesellschaft.

## Giessen (Hesse)—

Oberhessische Gesellschaft für Natur-und Heilkunde.

## Griefswald (Prussia)—

Geographische Gesellschaft.

## Halle (Prussia)—

Verein für Erdkunde.

Kaiserliche Leopoldina Carolina Akademie der Deutschen Naturforscher.

## Hamburg—

Geographische Gesellschaft.

## INDIA.

## Calcutta—

Geological Survey of India.

## IRELAND.

## Belfast—

Belfast Naturalists' Field Club.

Natural History and Philosophical Society.

## Dublin—

Royal Dublin Society.

Royal Irish Academy.

## ITALY.

## Milan—

Reale Istituto di Lombardo.

- Tokio— JAPAN.  
Imperial University of Japan (College of Medicine).  
Seismological Society of Japan.  
University of Tokio.
- Mexico— MEXICO.  
Observatorio Meteorológico-Magnetico Central de Mexico.  
Observatorio Astronómico Nacional de Tacubaya.  
Sociedad Científica "Antonio Alzate."
- Wellington— NEW ZEALAND.  
Colonial Museum.
- Amsterdam— NETHERLANDS.  
Academie Royale des Sciences.
- Harlem—  
La Société de Sciences à Harlem.  
Teyleryan Library.
- Leyden—  
Kon. Nederlandsch Aardrijkskundig Genootschap.
- Christiania— NORWAY.  
Kongelige Norske Universitet.
- Lisbon— PORTUGAL.  
Academia Real das Sciencias.
- Kazan— RUSSIA.  
Imperial Kazan University.
- St. Petersburg—  
Russian Chemical Society of the University of St. Petersburg.
- Aberdeen— SCOTLAND.  
Philosophical Society.
- Edinburgh—  
Advocates' Library.  
Geological Society.  
Royal Botanic Gardens.  
Royal Physical Society.  
Royal Scottish Geographical Society.  
Scottish Meteorological Society.  
Royal Scottish Society of Arts.  
Royal Society.
- Glasgow—  
Archæological Society.  
Faculty of Physicians and Surgeons of Glasgow.

*Voluntary Society of Glasgow.*  
*SCOTLAND—continued.*

*Glasgow—*  
*Technical Society.*  
*Glasgow and West of Scotland Technical College Library.*  
*Institution of Engineers and Shipbuilders in Scotland.*  
*Mitchell Library.*  
*Natural History Society of Glasgow.*  
*Stirling's Public Library.*

*Glasgow—*  
*Philosophical Society.*

*Hamilton—*  
*Mining Institute of Scotland.*  
*Public Library.*

*Paisley—*  
*Public Library.*

*Stockholm—* SWEDEN.  
*Kongliga Svenska Vetenskaps-Akademien.*

*Hobart Town—* TASMANIA.  
*Royal Society of Tasmania.*

*Baltimore—* UNITED STATES.  
*Johns Hopkins University.*

*Boston—*  
*American Academy of Arts and Sciences.*  
*Public Library.*  
*Society of Natural History.*

*Cincinnati—*  
*Ohio Mechanics' Institute.*

*Davenport (Iowa)—*  
*Academy of Natural Sciences.*

*Madison—*  
*Washburn Observatory.*

*Minneapolis—*  
*Geological and Natural History Society of Minnesota.*

*Newhaven (Conn.)—*  
*Connecticut Academy of Arts and Sciences.*

*New York—*  
*American Geographical Society.*  
*American Museum of Natural History.*  
*American Society of Civil Engineers.*  
*Astor Library.*  
*New York Academy of Sciences.*  
*School of Mines, Columbia College.*

UNITED STATES—*continued.*

## Philadelphia—

Academy of Natural Science of Philadelphia.  
 Alumni Association.  
 American Pharmaceutical Association.  
 American Philosophical Society.  
 Franklin Institute.  
 Numismatic and Antiquarian Society of Philadelphia.  
 Wagner Free Institute of Science.

## Rochester (N. Y.)—

Rochester Academy of Science.

## St. Louis—

Academy of Science.  
 Public School Library.

## San Francisco (California)—

California Academy of Sciences.

## Scranton (Pa.)—

Colliery Engineer Publishing Company.

## Topeka (Kansas)—

Kansas Academy of Science.

## Trenton (N. J.)—

Trenton Natural History Society.

## Washington—

Bureau of Education (Department of the Interior).  
 Smithsonian Institution.  
 United States Naval Observatory.  
 United States Geological Survey.

## LIST OF PERIODICALS.

(Those received in exchange are indicated by an asterisk.)

## WEEKLY.

Academy.	Engineering.
Architect.	English Mechanic.
Athenæum.	*Industries.
British Architect.	Iron.
British Journal of Photography.	*Journal of the Society of Arts.
Builder.	Journal of Gas Lighting, &c.
Building News.	*Lancet.
Chemical News.	Nature.
Comptes Rendus.	Notes and Queries.
Dingler's Polytechnisches Journal.	*Pharmaceutical Journal.
Economist.	Publishers' Circular.
Electrical Review.	Science.
Electrician.	Scientific American and Supplement.
Engineer.	

## FORTNIGHTLY.

Annalen der Chemie (Liebig's).	Journal für Praktische Chemie (Erdmann's).
Berichte der Deutschen Chemischen Gesellschaft.	Zeitschrift für Angewandte Chemie.

## MONTHLY.

*American Chemical Journal.	Entomologists' Monthly Magazine.
American Journal of Science.	Geological Magazine.
Analyst.	Hardwicke's Science Gossip.
Annalen der Physik und Chemie.	*Johns Hopkins University Circulars.
Annales de Chimie et de Physique.	Journal de Pharmacie et de Chimie.
Annales des Ponts et des Chaussées.	Journal of Botany.
Annales des Sciences Naturelles—Botanique.	*Journal of the Chemical Society.
Annales des Sciences Naturelles. (Zoologie.)	*Journal of the Franklin Institute.
Annals and Magazine of Natural History.	*Journal of the Photographic Society.
Antiquary.	*Journal of Society of Chemical Industry.
Beiblätter zu den Annalen der Physik und Chemie.	London, Edinburgh, and Dublin Philosophical Magazine.
*Boletín Mensuel d'Observatorio Meteorológico-Magnético Central de Mexico.	Midland Naturalist.
Bookseller.	*Monatsbericht der Königlich Preussischen Akademie der Wissenschaften zu Berlin.
Bulletin de la Société d'Encouragement.	Petermann's Mitteilungen.
Bulletin de la Société Géologique de France.	Polytechnic Bibliothek.
Bulletin de la Société Industrielle de Mulhouse.	*Proceedings of Royal Geographical Society.
*Bulletin Mensuel de l'Observatoire de Montsouris.	*Proceedings of Royal Society of London.
Canadian Entomologist.	*Proceedings of the Society of Biblical Archaeology.
Chamber of Commerce Journal.	Revue Universelle des Mines.
*Deutsche Kolonialzeitung.	Royal Astronomical Society's Monthly Notices.
Economic Journal.	Sanitary Journal.
Entomologist.	*Scottish Geographical Magazine.
	Zoologist.

## QUARTERLY.

Annales des Mines.	Grevillea.
Annals of Botany.	Ibis.
*Archives Néerlandaises des Sciences Exactes et Naturelles.	Journal of Anatomy and Physiology.
*Bulletin of the American Geographical Society.	*Journal of the Anthropological Institute of Great Britain.
Fortschritte der Mathematik.	*Journal of Manchester Geographical Society.

*Journal of the Royal Agricultural Society of England.	Quarterly Journal of Microscopical Science.
Journal of the Royal Statistical Society.	Quarterly Journal of Pure and Applied Mathematics.
*Journal of the Scottish Meteorological Society.	*School of Mines Quarterly.
La Nature.	Scottish Naturalist.
Mind: a Quarterly Review of Psychology and Philosophy.	*Sociedad Cientifica "Antonio Alzate."
Quarterly Journal of Economics.	Zeitschrift für Analytische Chemie.
Quarterly Journal of Geological Society.	

LIST OF MEMBERS  
OF THE  
PHILOSOPHICAL SOCIETY OF GLASGOW,  
FOR 1891-92.

HONORARY MEMBERS.

*(Limited to Twenty.)*

WITH YEAR OF ELECTION.

FOREIGN.

Hermann Ludwig Ferdinand von Helmholtz, Berlin. . . . .	1860
Rudolph Albert von Kölliker, Würzburg. . . . .	1860
Ernst Heinrich Hæckel, Jena. . . . .	1880
Louis Pasteur, Paris. . . . .	1885
5 Georg Quincke, Heidelberg. . . . .	1890

AMERICAN AND COLONIAL.

James Dwight Dana, LL.D., Professor of Geology and Mineralogy in Yale College, Connecticut. . . . .	1860
Robert Lewis John Ellery, F.R.A.S., Victoria. . . . .	1874
Sir John William Dawson, LL.D., F.R.S., Principal of M'Gill College, Montreal. . . . .	1883

BRITISH.

Sir Joseph Dalton Hooker, K.C.B., K.C.S.I., M.D., D.C.L., LL.D., F.R.S., The Camp, Sunningdale. . . . .	1874
10 Thomas Henry Huxley, Ph.D., LL.D., D.C.L., F.R.S., Professor of Biology in the Royal College of Science, London, Hodeslea, Eastbourne. . . . .	1876
Herbert Spencer, care of Messrs. Williams & Norgate, 14 Henrietta street, Covent Garden, London. . . . .	1879
John Tyndall, LL.D., D.C.L., F.R.S., M.R.I., Hind Head House, Haslemere, Surrey. . . . .	1880
Rev. John Kerr, LL.D., Glasgow. . . . .	1885
Sir George Gabriel Stokes, Bart., M.A., LL.D., D.C.L., F.R.S., M.P., Cambridge. . . . .	1887
15 F. Max Müller, M.A., Professor of Comparative Philology, Oxford. . . . .	1889
The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., London, Terling Place, Witham, Essex. . . . .	1890
Thomas Muir, M.A., LL.D., F.R.S.E., Superintendent General of Education, Cape Colony. . . . .	1892

## CORRESPONDING MEMBERS.

WITH YEAR OF ELECTION.

Rev. H. W. Crosskey, LL.D., F.G.S., 117 Gough road, Birmingham.	1874
A. S. Herschel, M.A., D.C.L., F.R.S., F.R.A.S., Hon. Professor of Experimental Physics in the Durham College of Science, Newcastle-on-Tyne; Observatory House, Slough, Bucks.	1874
Thomas E. Thorpe, Ph.D., F.R.S., Professor of Chemistry in Royal College of Science, London.	1874
John Aitken, F.R.S., F.R.S.E., Darroch, Falkirk.	1883
5 Alex. Buchan, M.A., LL.D., F.R.S.E., Secretary to the Scottish Meteorological Society, 122 George street, Edinburgh.	1883
James Dewar, M.A., F.R.S., F.R.S.E., M.R.I., Jacksonian Professor of Physics, University of Cambridge, and Professor of Chemistry in the Royal Institution of Great Britain, 1 Scroope terrace, Cambridge.	1883
Stevenson Macadam, Ph.D., F.R.S.E., Lecturer on Chemistry, Surgeons' Hall, Edinburgh.	1883
Joseph W. Swan, M.A., Lauriston, Bromley, Kent.	1883
E. A. Wünsch, F.G.S., Carharrack, Scorrior, Cornwall.	1883
10 George Anderson, Master of the Mint, Melbourne.	1885

## ORDINARY MEMBERS.

WITH YEAR OF ENTRY.

\* Denotes Life Members.

Adam, William, M.A., 235 Bath st.	1876	20 Arnot, James Craig, 162 St. Vincent street.	1869
Adams, William, 28 Ashton terrace, Dowanhill.	1891	Arnot, J. L., 116 West Campbell street.	1890
Aikman, C. M., M.A., B.Sc., F.R.S.E., F.I.C., F.C.S., Lecturer on Agricultural Chemistry, Technical College, 183 St. Vincent street.	1886	Arrol, Walter, 16 Dixon street.	1869
Aitken, William, National Telephone Company.	1890	Arrol, William A., 16 Dixon street.	1869
5 Alexander, D. M., 8 Royal crescent, Crosshill.	1887	Atkinson, J. B., 10 Foremount terrace, Partick.	1889
Alexander, Peter, M.A., 26 Smith street, Hillhead.	1885		
Alexander, Thos., 48 Sardinia ter.	1869	25 Bain, Andrew, 17 Athole gardens.	1890
Alley, Stephen, Sentinel Works, Polmadie road.	1884	Bain, Sir James, F.R.S.E., 3 Park terrace.	1866
Alston, J. Carfrae, 9 Lorraine gardens, Dowanhill.	1887	Bain, Robert, 132 West Nile street.	1869
10 Anderson, Alexander, 157 Trongate.	1869	Balloch, Robert, 131 St. Vincent street.	1843
Anderson, James, 168 George street.	1890	Balmain, Thos., 1 Kew terrace, Kelvinside.	1881
Anderson, John, 22 Ann street.	1884	30 Barbour, T. F., F.C.S., F.I.C., 35 Robertson street.	1891
Anderson, Robert, 22 Ann street.	1887	Barclay, A. P., 63 St. Vincent street.	1890
Anderson, R. T. R., 618 Gallowgate street.	1889	Barclay, George, 63 St. Vincent st.	1891
15* Anderson, T. M'Call, M.D., Professor of Clinical Medicine in the University of Glasgow, 2 Woodside terrace.	1873	Barclay, James, 36 Windsor terrace.	1871
*Anderson, William, 284 Buchanan street.	1890	Barrett, Francis Thornton, Mitchell Library.	1880
Anderson, W. F. G., 47 Union street.	1878	35 Barr, Archibald, D.Sc., Professor of Civil Engineering and Mechanics, University of Glasgow, Royston, Dowanhill.	1890
Annan, J. Craig, 234 Sauchiehall street.	1888	*Barr, James, C.E., I.M., 221 West George street.	1883
Annandale, Charles, M.A., LL.D., 86 Dixon avenue, Crosshill.	1888	Barr, Thos., M.D., F.F.P.S.G., 13 Woodside place, W.	1879
		Bathgate, William, M.A., 13 Westbourne gardens.	1887
		Bayne, A. Malloch, 13 Kelvin drive, Kelvinside. *	1878

- 40 Beaton, George T., B.A. (Cantab.),  
M.D., 2 Royal crescent. 1881  
Begg, Wm., 536 Springfield road. 1883  
\*Bentin, Gilbert M.P., 7 Royal Bank pl. 1881  
Bell, Dugald, 27 Lansdowne cres. 1871  
\*Bell, Henry, 5 Cornwall terrace,  
Regent's Park, London, N.W. 1875  
45 Bell, James, 7 Marlborough terrace,  
Kelvin-side. 1877  
Bennett, Robert J., Alloway park,  
Ayr. 1883  
Bilsland, William, 28 Park circus. 1888  
Binnie, J., Barassie, Troon. 1877  
Black, Adam Elliot, C.A., F.C.S.,  
5 Hillborough square, Bruce st.,  
Hillhead. 1880  
50 Black, D. Campbell, M.D., M.R.C.S.E.,  
121 Douglas street. 1872  
Black, J. Albert, Dunera, Row. 1869  
Black, John, 16 Park terrace. 1869  
Black, Malcolm, M.B., C.M., 5 Can-  
ning place. 1880  
\*Blackie, J. Alexander, 17 Stanhope  
street. 1881  
55\* Blackie, J. Robertson, 17 Stanhope  
street. 1881  
Blackie, Robert, 17 Stanhope st. 1847  
Blackie, W. G., Ph.D., LL.D.,  
F.R.G.S., 17 Stanhope street. 1841  
Blackie, Walter W., B.Sc., 17 Stan-  
hope street. 1886  
Blair, G. M'Lellan, 2 Lilybank  
terrace. 1869  
60 Blair, J. M'Lellan, Williamcraig,  
Linlithgowshire. 1869  
Blair, Matthew, 11 Hampton Court  
terrace. 1887  
Blyth, James, M.A., F.R.S.E., Pro-  
fessor of Natural Philosophy,  
Andersonian Buildings, 204  
George street. 1881  
\*Blyth, Robert, C.A., 1 Montgomerie  
quadrant. 1885  
Borthwick, James D., 3 Balshagray  
terrace, Partick. 1891  
65 Bost, Timothy, 33 Renfield street. 1876  
Bottomley, James T., M.A., D.Sc.,  
F.R.S., F.R.S.E., F.C.S., Demon-  
strator in Natural Philosophy,  
University of Glasgow, 13 Uni-  
versity gardens, Hillhead, Vice-  
President. 1880  
Bottomley, Wm., C.E., 15 University  
gardens. 1880  
Bower, F. O., D.Sc., M.A., F.R.S.,  
F.L.S., Regius Professor of Bot-  
any in the University of Glasgow,  
45 Kersland terrace. 1885  
Boyd, John, Shettleston Iron-works,  
near Glasgow. 1873  
70 Brand, James, C.E., 172 Buchanan  
street. 1880  
Brier, Henry, M.I.M.E., Scotch and  
Irish Oxygen Co., Polmadie. 188  
Brodie, John Ewan, M.D., C.M.,  
F.F.P.S.G., 1 Albany place. 187  
Brodie, Maclean, C.A., 44 West-  
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75\* Brown, Hugh, 5 St. John's terrace,  
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Brown, James, 75 St. Vincent st. 187  
\*Brown, John, 11 Somerset place. 188  
Brown, Robert, 19 Jamaica street. 188  
\*Brown, Wm. Stevenson, 41 Oswald  
street. 188  
80\* Brown, William, 155 West George st. 189  
Brownie, Archibald, Bank of Scot-  
land, Barrhead. 188  
Brunton, Rev. Alex., Ardbeg villa,  
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\*Bryce, Charles C., 141 West George  
street. 188  
Bryce, David, 129 Buchanan street. 187  
85\* Bryce, Robert, 82 Oswald street. 188  
\*Buchan, William P., 36 & 38 Ren-  
frew street. 187  
Buchanan, Alex. M., A.M., M.D.,  
Professor of Anatomy, Anderson's  
College Medical School, 98 St.  
George's road. 187  
Buchanan, George S., 85 Candle-  
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\*Buchanan, William, 123 Blythwood  
drive. 188  
90 Burnet, John, I.A., 167 St. Vincent  
street. 185  
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St. Kilda, Dowanhill. 188  
Burns, J., M.D., 15 Fitzroy place,  
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Regent street. 188  
Callajon, Ventura De, jun., 7  
Woodlands terrace. 189  
95 Cameron, Charles, M.D., LL.D.,  
M.P., Greenock. 1870  
Cameron, H. C., M.D., 200 Bath  
street. 1873  
Cameron, John E., 115 Bothwell st. 1892  
Cameron, R., Wellpark, Bathgate. 1873  
\*Campbell, The Right Hon. Lord, of  
Blythwood, Renfrew. 1885  
100\* Campbell, J. A., LL.D., M.P.,  
Strathcathro, Brechin. 1848  
\*Campbell, James, 137 Ingram st. 1885  
Campbell, John D., Greenside,  
North avenue, Copeland road,  
Govan. 1858  
Campbell, John MacNaught, C.E.,  
F.Z.S., F.R.S.G.S., Kelvingrove  
Museum. 1883

- \*Campbell, Louis, 3 Eton terrace,  
Hillhead. 1881
- 15 Carlile, Thomas, 23 West Nile  
street. 1851
- Carmichael, Neil, M.D., C.M.,  
F.F.P.S.G., Invercarmel, 23  
Nithsdale drive, Pollokshields. 1873
- Carver, Thomas, A.B., B.Sc., C.E.,  
Oswald hill, Partick. 1890
- Cassells, John, 62 Glencairn drive,  
Pollokshields. 1890
- \*Cayzer, Charles W., 109 Hope  
street. 1886
- 10 Chalmers, James, I.A., 101 St. Vin-  
cent street. 1884
- Chalmers, P. Macgregor, F.S.A.Scot.,  
176½ Hope street. 1891
- Cherrie, James M., Clutha cottage,  
Tollcross. 1876
- \*Chisholm, Samuel, 4 Royal ter., W. 1890
- Christie, John, Turkey-red Works,  
Alexandria, Dumbartonshire. 1868
- 15 Chrystal, W. J., F.I.C., F.C.S.,  
Shawfield Works, Rutherglen. 1882
- Church, W. R. M., C.A., 75 St.  
George's place. 1885
- Clapperton, Charles, 16 Lilybank  
gardens, Hillhead. 1882
- Clapperton, John, 9 Crown Circus  
drive. 1874
- Clark, John, Ph.D., F.I.C., F.C.S.,  
138 Bath street. 1870
- 20 Clark, John, 9 Wilton crescent. 1872
- \*Clark, William, 125 Buchanan st. 1876
- Clavering, Thos., 27 St. Vincent  
place. 1856
- Cleland, A. B. Dick, 15 Newton  
place. 1871
- \*Cleland, John, M.D., LL.D., D.Sc.,  
F.R.S., Professor of Anatomy  
in the University of Glasgow. 1884
- 25 \*Coats, Joseph, M.D., 31 Lynedoch  
street. 1873
- \*Cochran, Robert, 7 Crown circus,  
Dowanhill. 1877
- Coghill, Wm. C., 263 Argyle street. 1873
- Collins, Sir William, F.R.G.S., 3  
Park terrace, East. 1869
- Colquhoun, James, 158 St. Vincent  
street. 1876
- 30 Colville, James, M.A., D.Sc., 14  
Newton place. 1885
- Combe, William, 257 W. Campbell  
street. 1877
- Connal, Sir Michael, Virginia bdgs. 1848
- Connell, Wm., 38 St. Enoch square. 1870
- Copeland, Jas., 7 Dundonald road,  
Kelvinside. 1869
- 35 Copland, Wm. R., M. Inst. C.E.,  
146 West Regent street. 1876
- Core, William, M.D., Medical Sup-  
erintendent, Barnhill Hospital. 1891
- Coste, Jules, French Consulate, 131 -  
West Regent street. 1888
- Costigane, John T., Hampton house,  
Ibros. 1889
- Costigane, William, Clifton house,  
Pollokshields. 1890
- 140 Coubrough, A. Sykes, Parklea,  
Blane field, Strathblane. 1869
- Coulson, W. Arthur, 56 George sq. 1888
- Couper, James, Craigforth house,  
Stirling. 1862
- Cowan, M. Taggart, C.E., 27 Ashton  
terrace, Hillhead. 1876
- Craig, T. A., C.A., 139 St. Vincent  
street. 1886
- 145 Crawford, Robert, 84 Miller st. 1886
- Crawford, Wm. C., M.A., Lock-  
harton gardens, Slateford, Edin-  
burgh. 1869
- Cree, Thomas S., 21 Exchange sq. 1869
- Crosbie, L. Talbot, Scotstounhill,  
Whiteinch. 1890
- Cross, Alexander, 14 Woodlands  
terrace. 1887
- 150 Cruikshank, George M., 62 St.  
Vincent street. 1885
- Cumming, Thos., 14 Montgomerie  
crescent. 1888
- Cunningham, John M., 18 Woodside  
terrace. 1881
- Cunningham, J. R., jun., 27 Oswald  
street. 1881
- Curphey, Wm. Salvador, 15 Bute  
mansions, Hillhead. 1883
- 155 Cuthbert, Alexander A., 14 Newton  
terrace. 1885
- \*Cuthbertson, Sir John N., 29 Bath  
street. 1850
- Dansken, A. B., 179 West George st. 1877
- \*Dansken, John, I.M., 121 West  
Regent street. 1876
- Darling, Geo. E., 178 St. Vincent st. 1870
- 160 Darwin, Harry, St. Andrew's  
Works, 618 Eglinton street. 1891
- Deas, Jas., C.E., 7 Crown gardens,  
Dowanhill. 1869
- Dempster, John, 4 Belmar terrace,  
Pollokshields. 1875
- Dennison, William, C.E., 175 Hope  
street. 1876
- Dewar, Duncan, St. Fillans, West  
Coates, Cambuslang. 1877
- 165 \*Dick, George Handasyde, 136  
Buchanan street. 1887
- \*Dixon, A. Dow, 10 Montgomerie  
crescent, Kelvin side. 1873
- Dobbie, A. B., M.A., University. 1885
- Donald, John, Townhead Public  
School. 1872
- Donald, William J. A., 70 Great  
Clyde street. 1877

CANADA—*continued.*

## Montreal—

Canadian Society of Civil Engineers.  
Geological and Natural History Survey of Canada.  
Royal Society of Canada.

## Quebec—

Literary and Historical Society.

## Toronto—

Canadian Institute.

## Winnipeg—

Manitoba Historical and Scientific Society.

## CHILI.

## Santiago—

Sociedad Cientifica Alemana.

## CHINA.

## Hong Kong—

Hong Kong Observatory.

## ENGLAND AND WALES.

## Barnsley—

Midland Institute of Mining, Civil, and Mechanical Engineers.

## Bath—

Bath Natural History and Antiquarian Field Club.

## Berwick—

Berwickshire Naturalists' Field Club.

## Birkenhead—

Birkenhead Literary and Scientific Society.

## Birmingham—

Philosophical Society.

## Bristol—

Bristol Naturalists' Society.

## Cambridge—

Philosophical Society.  
University Library.

## Cardiff—

Cardiff Naturalists' Society.

## Essex—

Essex Field Club.

## Falmouth—

Royal Cornwall Polytechnic Society.

## Folkestone—

Folkestone Natural History Society.

## Greenwich—

Royal Observatory.

## Leeds—

Leeds Philosophical and Literary Society.

ENGLAND AND WALES—*continued.*

Leicester—

Leicester Literary and Philosophical Society.

Liverpool—

Geological Society.

Historic Society of Lancashire and Cheshire.

Literary and Philosophical Society.

Liverpool Engineering Society.

Liverpool Naturalists' Field Club.

London—

Anthropological Institute.

Architects' Register.

British Museum.

British Museum (Nat. His.).

London—

Chemical Society.

Institution of Civil Engineers.

Institution of Mechanical Engineers.

Junior Engineering Society.

Middlesex Hospital.

Patent Office Library.

Pharmaceutical Society.

Photographic Society.

Physical Society of London.

Royal Geographical Society.

Royal Institute of British Architects.

Royal Institution of Great Britain.

Royal Meteorological Society.

Royal Society.

Royal Statistical Society.

Society of Arts.

Society of Biblical Archæology.

Society of Engineers.

Society of Psychical Research.

*The Lancet.*

Manchester—

Manchester Association of Engineers.

Geographical Society.

Literary and Philosophical Society of Manchester.

*Industries.*

Middlesborough—

Cleveland Institution of Engineers.

Newcastle-upon-Tyne—

North-East Coast Institution of Engineers and Shipbuilders.

North of England Institute of Mining and Mechanical Engineers.

Society of Chemical Industry.

ENGLAND AND WALES—*continued.*

## Swansea—

South Wales Institute of Engineers.

## Truro—

Royal Institution of Cornwall.

## Watford—

Hertfordshire Natural History Society and Field Club.

## Welshpool—

Powys Land Club.

## FRANCE.

## Bordeaux—

Société des Sciences Physiques et Naturelles.

## Paris—

École Polytechnique.

Observatoire Météorologique Central de Montsouris.

## GERMANY.

## Berlin—

Deutsche Chemische Gesellschaft.

Deutscher Kolonial Verein.

Königlich Preussische Akademie der Wissenschaften.

## Bremen—

Geographische Gesellschaft.

## Giessen (Hesse)—

Oberhessische Gesellschaft für Natur-und Heilkunde.

## Griefswald (Prussia)—

Geographische Gesellschaft.

## Halle (Prussia)—

Verein für Erdkunde.

Kaiserliche Leopoldina Carolina Akademie der Deutschen Naturforscher.

## Hamburg—

Geographische Gesellschaft.

## INDIA.

## Calcutta—

Geological Survey of India.

## IRELAND.

## Belfast—

Belfast Naturalists' Field Club.

Natural History and Philosophical Society.

## Dublin—

Royal Dublin Society.

Royal Irish Academy.

## ITALY.

## Milan—

Reale Istituto di Lombardo.

- Tokio— JAPAN.  
Imperial University of Japan (College of Medicine).  
Seismological Society of Japan.  
University of Tokio.
- Mexico— MEXICO.  
Observatorio Meteorológico-Magnetico Central de Mexico.  
Observatorio Astronómico Nacional de Tacubaya.  
Sociedad Científica "Antonio Alzate."
- Wellington— NEW ZEALAND.  
Colonial Museum.
- Amsterdam— NETHERLANDS.  
Academie Royale des Sciences.
- Harlem—  
La Société de Sciences à Harlem.  
Teyleryan Library.
- Leyden—  
Kon. Nederlandsch Aardrijkskundig Genootschap.
- Christiania— NORWAY.  
Kongelige Norske Universitet.
- Lisbon— PORTUGAL.  
Academia Real das Sciencias.
- Kazan— RUSSIA.  
Imperial Kazan University.
- St. Petersburg—  
Russian Chemical Society of the University of St. Petersburg.
- Aberdeen— SCOTLAND.  
Philosophical Society.
- Edinburgh—  
Advocates' Library.  
Geological Society.  
Royal Botanic Gardens.  
Royal Physical Society.  
Royal Scottish Geographical Society.  
Scottish Meteorological Society.  
Royal Scottish Society of Arts.  
Royal Society.
- Glasgow—  
Archæological Society.  
Faculty of Physicians and Surgeons of Glasgow.

SCOTLAND—*continued.*

## Glasgow—

Geological Society.

Glasgow and West of Scotland Technical College Library.

Institution of Engineers and Shipbuilders in Scotland.

Mitchell Library.

Natural History Society of Glasgow.

Stirling's Public Library.

## Greenock—

Philosophical Society.

## Hamilton—

Mining Institute of Scotland.

Public Library.

## Paisley—

Public Library.

## Stockholm—

## SWEDEN.

Kongliga Svenska Vetenskaps-Akademien.

## Hobart Town—

## TASMANIA.

Royal Society of Tasmania.

## Baltimore—

## UNITED STATES.

Johns Hopkins University.

## Boston—

American Academy of Arts and Sciences.

Public Library.

Society of Natural History.

## Cincinnati—

Ohio Mechanics' Institute.

## Davenport (Iowa)—

Academy of Natural Sciences.

## Madison—

Washburn Observatory.

## Minneapolis—

Geological and Natural History Society of Minnesota.

## Newhaven (Conn.)—

Connecticut Academy of Arts and Sciences.

## New York—

American Geographical Society.

American Museum of Natural History.

American Society of Civil Engineers.

Astor Library.

New York Academy of Sciences.

School of Mines, Columbia College.

UNITED STATES—*continued.*

## Philadelphia—

Academy of Natural Science of Philadelphia.

Alumni Association.

American Pharmaceutical Association.

American Philosophical Society.

Franklin Institute.

Numismatic and Antiquarian Society of Philadelphia.

Wagner Free Institute of Science.

## Rochester (N. Y.)—

Rochester Academy of Science.

## St. Louis—

Academy of Science.

Public School Library.

## San Francisco (California)—

California Academy of Sciences.

## Scranton (Pa.)—

Colliery Engineer Publishing Company.

## Topeka (Kansas)—

Kansas Academy of Science.

## Trenton (N. J.)—

Trenton Natural History Society.

## Washington—

Bureau of Education (Department of the Interior).

Smithsonian Institution.

United States Naval Observatory.

United States Geological Survey.

## LIST OF PERIODICALS.

*(Those received in exchange are indicated by an asterisk.)*

## WEEKLY.

Academy.	Engineering.
Architect.	English Mechanic.
Athenæum.	*Industries.
British Architect.	Iron.
British Journal of Photography.	*Journal of the Society of Arts.
Builder.	Journal of Gas Lighting, &c.
Building News.	*Lancet.
Chemical News.	Nature.
Comptes Rendus.	Notes and Queries.
Dingler's Polytechnisches Journal.	*Pharmaceutical Journal.
Economist.	Publishers' Circular.
Electrical Review.	Science.
Electrician.	Scientific American and Supple-
Engineer.	ment.

## FORTNIGHTLY.

Annalen der Chemie (Liebig's).	Journal für Praktische Chemie (Erdmann's).
Berichte der Deutschen Chemischen Gesellschaft.	Zeitschrift für Angewandte Chemie.

## MONTHLY.

*American Chemical Journal.	Entomologists' Monthly Magazine.
American Journal of Science.	Geological Magazine.
Analyst.	Hardwicke's Science Gossip.
Annalen der Physik und Chemie.	*Johns Hopkins University Circulars.
Annales de Chimie et de Physique.	Journal de Pharmacie et de Chimie.
Annales de l'Institut Pasteur.	Journal of Botany.
Annales des Ponts et des Chaussées.	*Journal of the Chemical Society.
Annales des Sciences Naturelles—Botanique.	*Journal of the Franklin Institute.
Annales des Sciences Naturelles. (Zoologie.)	*Journal of the Photographic Society.
Annals and Magazine of Natural History.	*Journal of Society of Chemical Industry.
Antiquary.	London, Edinburgh, and Dublin Philosophical Magazine.
Beiblätter zu den Annalen der Physik und Chemie.	Midland Naturalist.
*Boletín Mensual d'Observatorio Meteorológico-Magnético Central de Mexico.	*Monatsbericht der Königlich Preussischen Akademie der Wissenschaften zu Berlin.
Bookseller.	Petermann's Mittheilungen.
Bulletin de la Société d'Encouragement.	Polytechnic Bibliothek.
Bulletin de la Société Géologique de France.	*Proceedings of Royal Geographical Society.
Bulletin de la Société Industrielle de Mulhouse.	*Proceedings of Royal Society of London.
*Bulletin Mensuel de l'Observatoire de Montsouris.	*Proceedings of the Society of Biblical Archaeology.
Canadian Entomologist.	Revue Universelle des Mines.
Chamber of Commerce Journal.	Royal Astronomical Society's Monthly Notices.
*Deutsche Kolonialzeitung.	Sanitary Journal.
Economic Journal.	*Scottish Geographical Magazine.
Entomologist.	Zoologist.

## QUARTERLY.

Annales des Mines.	Grevillea.
Annals of Botany.	Ibis.
*Archives Néerlandaises des Sciences Exactes et Naturelles.	Journal of Anatomy and Physiology.
*Bulletin of the American Geographical Society.	*Journal of the Anthropological Institute of Great Britain.
Forschritte der Mathematik.	*Journal of Manchester Geographical Society.

*Journal of the Royal Agricultural Society of England.	Quarterly Journal of Microscopical Science.
Journal of the Royal Statistical Society.	Quarterly Journal of Pure and Applied Mathematics.
*Journal of the Scottish Meteorological Society.	*School of Mines Quarterly.
La Nature.	Scottish Naturalist.
Mind: a Quarterly Review of Psychology and Philosophy.	*Sociedad Cientifica "Antonio Alzate."
Quarterly Journal of Economics.	Zeitschrift für Analytische Chemie.
Quarterly Journal of Geological Society.	

LIST OF MEMBERS  
OF THE  
PHILOSOPHICAL SOCIETY OF GLASGOW,  
FOR 1891-92.

HONORARY MEMBERS.

(*Limited to Twenty.*)

WITH YEAR OF ELECTION.

FOREIGN.

Hermann Ludwig Ferdinand von Helmholtz, Berlin. . . . .	1860
Rudolph Albert von K�lliker, W�rtzburg. . . . .	1860
Ernst Heinrich H�ckel, Jena. . . . .	1880
Louis Pasteur, Paris. . . . .	1885
5 Georg Quincke, Heidelberg. . . . .	1890

AMERICAN AND COLONIAL.

James Dwight Dana, LL.D., Professor of Geology and Mineralogy in Yale College, Connecticut. . . . .	1860
Robert Lewis John Ellery, F.R.A.S., Victoria. . . . .	1874
Sir John William Dawson, LL.D., F.R.S., Principal of M'Gill College, Montreal. . . . .	1883

BRITISH.

Sir Joseph Dalton Hooker, K.C.B., K.C.S.I., M.D., D.C.L., LL.D., F.R.S., The Camp, Sunningdale. . . . .	1874
10 Thomas Henry Huxley, Ph.D., LL.D., D.C.L., F.R.S., Professor of Biology in the Royal College of Science, London, Hodeslea, Eastbourne. . . . .	1876
Herbert Spencer, care of Messrs. Williams & Norgate, 14 Henrietta street, Covent Garden, London. . . . .	1879
John Tyndall, LL.D., D.C.L., F.R.S., M.R.I., Hind Head House, Haslemere, Surrey. . . . .	1880
Rev. John Kerr, LL.D., Glasgow. . . . .	1885
Sir George Gabriel Stokes, Bart., M.A., LL.D., D.C.L., F.R.S., M.P., Cambridge. . . . .	1887
15 F. Max M�ller, M.A., Professor of Comparative Philology, Oxford. . . . .	1889
The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., London, Terling Place, Witham, Essex. . . . .	1890
Thomas Muir, M.A., LL.D., F.R.S.E., Superintendent General of Education, Cape Colony. . . . .	1892

## CORRESPONDING MEMBERS.

WITH YEAR OF ELECTION.

Rev. H. W. Crosskey, LL.D., F.G.S., 117 Gough road, Birmingham.	1874
A. S. Herschel, M.A., D.C.L., F.R.S., F.R.A.S., Hon. Professor of Experimental Physics in the Durham College of Science, Newcastle-on-Tyne; Observatory House, Slough, Bucks.	1874
Thomas E. Thorpe, Ph.D., F.R.S., Professor of Chemistry in Royal College of Science, London.	1874
John Aitken, F.R.S., F.R.S.E., Darroch, Falkirk.	1883
5 Alex. Buchan, M.A., LL.D., F.R.S.E., Secretary to the Scottish Meteorological Society, 122 George street, Edinburgh.	1883
James Dewar, M.A., F.R.S., F.R.S.E., M.R.I., Jacksonian Professor of Physics, University of Cambridge, and Professor of Chemistry in the Royal Institution of Great Britain, 1 Scroope terrace, Cambridge.	1883
Stevenson Macadam, Ph.D., F.R.S.E., Lecturer on Chemistry, Surgeons' Hall, Edinburgh.	1883
Joseph W. Swan, M.A., Lauriston, Bromley, Kent.	1883
E. A. Wunsch, F.G.S., Carharrack, Scorrior, Cornwall.	1883
10 George Anderson, Master of the Mint, Melbourne.	1885

## ORDINARY MEMBERS.

WITH YEAR OF ENTRY.

\* Denotes Life Members.

Adam, William, M.A., 235 Bath st.	1876	20 Arnot, James Craig, 162 St. Vincent street.	1869
Adams, William, 28 Ashton terrace, Dowanhill.	1891	Arnot, J. L., 116 West Campbell street.	1890
Aikman, C. M., M.A., B.Sc., F.R.S.E., F.I.C., F.C.S., Lecturer on Agricultural Chemistry, Technical College, 183 St. Vincent street.	1886	Arrol, Walter, 16 Dixon street.	1869
Aitken, William, National Telephone Company.	1890	Arrol, William A., 16 Dixon street.	1869
5 Alexander, D. M., 8 Royal crescent, Crosshill.	1887	Atkinson, J. B., 10 Foremount terrace, Partick.	1889
Alexander, Peter, M.A., 26 Smith street, Hillhead.	1885	25 Bain, Andrew, 17 Athole gardens.	1890
Alexander, Thos., 48 Sardinia ter.	1869	Bain, Sir James, F.R.S.E., 3 Park terrace.	1866
Alley, Stephen, Sentinel Works, Polmadie road.	1884	Bain, Robert, 132 West Nile street.	1869
Alston, J. Carfrae, 9 Lorraine gardens, Dowanhill.	1887	Balloch, Robert, 131 St. Vincent street.	1843
10 Anderson, Alexander, 157 Trongate.	1869	Balmain, Thos., 1 Kew terrace, Kelvinside.	1881
Anderson, James, 168 George street.	1890	30 Barbour, T. F., F.C.S., F.I.C., 35 Robertson street.	1891
Anderson, John, 22 Ann street.	1884	Barclay, A. P., 63 St. Vincent street.	1890
Anderson, Robert, 22 Ann street.	1887	Barclay, George, 63 St. Vincent st.	1891
Anderson, R. T. R., 618 Gallowgate street.	1889	Barclay, James, 36 Windsor terrace.	1871
15* Anderson, T. M'Call, M.D., Professor of Clinical Medicine in the University of Glasgow, 2 Woodside terrace.	1873	Barrett, Francis Thornton, Mitchell Library.	1880
*Anderson, William, 284 Buchanan street.	1890	35 Barr, Archibald, D.Sc., Professor of Civil Engineering and Mechanics, University of Glasgow, Royston, Dowanhill.	1890
Anderson, W. F. G., 47 Union street.	1878	*Barr, James, C.E., I.M., 221 West George street.	1883
Annan, J. Craig, 234 Sauchiehall street.	1888	Barr, Thos., M.D., F.F.P.S.G., 13 Woodside place, W.	1879
Anandale, Charles, M.A., LL.D., 86 Dixon avenue, Crosshill.	1888	Bathgate, William, M.A., 13 Westbourne gardens.	1887
		Bayne, A. Malloch, 13 Kelvin drive, Kelvinside.	1878

- 40 Beatson, George T., B.A. (Cantab.),  
M.D., 2 Royal crescent. 1881  
Begg, Wm., 636 Springfield road. 1883  
\*Beith, Gilbert, M.P., 7 Royal Bank pl. 1881  
Bell, Dugald, 27 Lansdowne cres. 1871  
\*Bell, Henry, 5 Cornwall terrace,  
Regent's Park, London, N.W. 1876  
45 Bell, James, 7 Marlborough terrace,  
Kelvinside. 1877  
Bennett, Robert J., Alloway park,  
Ayr. 1883  
Bilsland, William, 28 Park circus. 1888  
Binnie, J., Barassie, Troon. 1877  
Black, Adam Elliot, C.A., F.C.S.,  
5 Hillsborough square, Bruce st.,  
Hillhead. 1880  
50 Black, D. Campbell, M.D., M.R.C.S.E.,  
121 Douglas street. 1872  
Black, J. Albert, Duneira, Row. 1869  
Black, John, 16 Park terrace. 1869  
Black, Malcolm, M.B., C.M., 5 Can-  
ning place. 1880  
\*Blackie, J. Alexander, 17 Stanhope  
street. 1881  
55 \*Blackie, J. Robertson, 17 Stanhope  
street. 1881  
Blackie, Robert, 17 Stanhope st. 1847  
Blackie, W. G., Ph.D., LL.D.,  
F.R.G.S., 17 Stanhope street. 1841  
Blackie, Walter W., B.Sc., 17 Stan-  
hope street. 1886  
Blair, G. M'Lellan, 2 Lilybank  
terrace. 1869  
60 Blair, J. M'Lellan, Williamcraig,  
Linlithgowshire. 1869  
Blair, Matthew, 11 Hampton Court  
terrace. 1887  
Blyth, James, M.A., F.R.S.E., Pro-  
fessor of Natural Philosophy,  
Andersonian Buildings, 204  
George street. 1881  
\*Blyth, Robert, C.A., 1 Montgomerie  
quadrant. 1885  
Borthwick, James D., 3 Balshagray  
terrace, Partick. 1891  
65 Bost, Timothy, 33 Renfield street. 1876  
Bottomley, James T., M.A., D.Sc.,  
F.R.S., F.R.S.E., F.C.S., Demon-  
strator in Natural Philosophy,  
University of Glasgow, 13 Uni-  
versity gardens, Hillhead, Vice-  
President. 1880  
Bottomley, Wm., C.E., 15 University  
gardens. 1880  
Bower, F. O., D.Sc., M.A., F.R.S.,  
F.L.S., Regius Professor of Bot-  
any in the University of Glasgow,  
45 Kersland terrace. 1885  
Boyd, John, Shettleston Iron-works,  
near Glasgow. 1873  
70 Brand, James, C.E., 172 Buchanan  
street. 1880  
Brier, Henry, M.I.M.E., Scotch and  
Irish Oxygen Co., Polmadie. 18  
Brodie, John Ewan, M.D., C.M.,  
F.F.P.S.G., 1 Albany place. 18  
Brodie, Maclean, C.A., 44 West-  
bourne gardens. 18  
Brown, Alexander, 3 Queen's ter. 18  
75 \*Brown, Hugh, 5 St. John's terrace,  
Hillhead. 18  
Brown, James, 76 St. Vincent st. 18  
\*Brown, John, 11 Somerset place. 18  
Brown, Robert, 19 Jamaica street. 18  
\*Brown, Wm. Stevenson, 41 Oswald  
street. 18  
80 \*Brown, William, 165 West George st. 18  
Brownlie, Archibald, Bank of Scot-  
land, Barrhead. 18  
Brunton, Rev. Alex., Ardbeg villa,  
Craigpark, Dennistoun. 18  
\*Bryce, Charles C., 141 West George  
street. 18  
Bryce, David, 129 Buchanan street. 18  
85 \*Bryce, Robert, 82 Oswald street. 18  
\*Buchan, William P., 36 & 38 Ren-  
frew street. 18  
Buchanan, Alex. M., A.M., M.D.,  
Professor of Anatomy, Anderson's  
College Medical School, 98 St.  
George's road. 18  
Buchanan, George S., 85 Candle-  
riggs. 18  
\*Buchanan, William, 123 Blythwood  
drive. 18  
90 Burnet, John, I.A., 167 St. Vincent  
street. 18  
Burnet, Lindsay, Assoc. M.I.C.E.,  
St. Kilda, Dowanhill. 18  
Burns, J., M.D., 15 Fitzroy place,  
Sauchiehall street. 18  
Callajon, Ventura De, 131 West  
Regent street. 18  
Callajon, Ventura De, jun., 7  
Woodlands terrace. 18  
95 Cameron, Charles, M.D., LL.D.,  
M.P., Greenock. 18  
Cameron, H. C., M.D., 200 Bath  
street. 18  
Cameron, John E., 115 Bothwell st. 18  
Cameron, R., Wellpark, Bathgate. 18  
\*Campbell, The Right Hon. Lord, of  
Blythwood, Renfrew. 18  
100 \*Campbell, J. A., LL.D., M.P.,  
Strathcathro, Brechin. 18  
\*Campbell, James, 137 Ingram st. 18  
Campbell, John D., Greenside,  
North avenue, Copeland road,  
Govan. 18  
Campbell, John MacNaught, C.E.,  
F.Z.S., F.R.S.G.S., Kelvingrove  
Museum. 18

- \*Campbell, Louis, 3 Eton terrace, Hillhead. 1881
- 15 Carlile, Thomas, 23 West Nile street. 1851
- Carmichael, Neil, M.D., C.M., F. F. P. S. G., Invercarmel, 23 Nithsdale drive, Pollokshields. 1873
- Carver, Thomas, A. B., B.Sc., C.E., Oswald hill, Partick. 1890
- Cassells, John, 62 Glencairn drive, Pollokshields. 1890
- \*Cayzer, Charles W., 109 Hope street. 1886
- 10 Chalmers, James, I.A., 101 St. Vincent street. 1884
- Chalmers, P. Macgregor, F.S.A.Scot., 176½ Hope street. 1891
- Cherrie, James M., Clutha cottage, Tolleross. 1876
- \*Chisholm, Samuel, 4 Royal ter., W. 1890
- Christie, John, Turkey-red Works, Alexandria, Dumbartonshire. 1868
- 15 Chrystal, W. J., F.I.C., F.C.S., Shawfield Works, Rutherglen. 1882
- Church, W. R. M., C.A., 75 St. George's place. 1885
- Clapperton, Charles, 16 Lilybank gardens, Hillhead. 1882
- Clapperton, John, 9 Crown Circus drive. 1874
- Clark, John, Ph.D., F.I.C., F.C.S., 138 Bath street. 1870
- 20 Clark, John, 9 Wilton crescent. 1872
- \*Clark, William, 125 Buchanan st. 1876
- Clavering, Thos., 27 St. Vincent place. 1856
- Cleland, A. B. Dick, 15 Newton place. 1871
- \*Cleland, John, M.D., LL.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 1884
- 25\*Coats, Joseph, M.D., 31 Lynedoch street. 1873
- \*Cochran, Robert, 7 Crown circus, Dowanhill. 1877
- Coghill, Wm. C., 263 Argyle street. 1873
- Collins, Sir William, F.R.G.S., 3 Park terrace, East. 1869
- Colquhoun, James, 158 St. Vincent street. 1876
- 30 Colville, James, M.A., D.Sc., 14 Newton place. 1885
- Combe, William, 257 W. Campbell street. 1877
- Connal, Sir Michael, Virginia bdgs. 1848
- Connell, Wm., 38 St. Enoch square. 1870
- Copeland, Jas., 7 Dundonald road, Kelvinside. 1869
- 35 Copland, Wm. R., M. Inst. C.E., 146 West Regent street. 1876
- Core, William, M.D., Medical Superintendent, Barnhill Hospital. 1891
- Coste, Jules, French Consulate, 131 West Regent street. 1888
- Costigane, John T., Hampton house, Ibrox. 1889
- Costigane, William, Clifton house, Pollokshields. 1890
- 140 Coubrough, A. Sykes, Parklea, Blane field, Strathblane. 1869
- Coulson, W. Arthur, 56 George sq. 1888
- Couper, James, Craigforth house, Stirling. 1862
- Cowan, M'Taggart, C.E., 27 Ashton terrace, Hillhead. 1876
- Craig, T. A., C.A., 139 St. Vincent street. 1886
- 145 Crawford, Robert, 84 Miller st. 1886
- Crawford, Wm. C., M.A., Lockharton gardens, Slateford, Edinburgh. 1869
- Cree, Thomas S., 21 Exchange sq. 1869
- Crosbie, L. Talbot, Scotstounhill, Whiteinch. 1890
- Cross, Alexander, 14 Woodlands terrace. 1887
- 150 Cruikshank, George M., 62 St. Vincent street. 1885
- Cumming, Thos., 14 Montgomerie crescent. 1888
- Cunningham, John M., 18 Woodside terrace. 1881
- Cunningham, J. R., jun., 27 Oswald street. 1881
- Curphey, Wm. Salvador, 15 Bute mansions, Hillhead. 1883
- 155 Cuthbert, Alexander A., 14 Newton terrace. 1885
- \*Cuthbertson, Sir John N., 29 Bath street. 1850
- Dansken, A. B., 179 West George st. 1877
- \*Dansken, John, I.M., 121 West Regent street. 1876
- Darling, Geo. E., 178 St. Vincent st. 1870
- 160 Darwin, Harry, St. Andrew's Works, 618 Eglinton street. 1891
- Deas, Jas., C.E., 7 Crown gardens, Dowanhill. 1869
- Dempster, John, 4 Belmar terrace, Pollokshields. 1875
- Dennison, William, C.E., 175 Hope street. 1876
- Dewar, Duncan, St. Fillans, West Coates, Cambuslang. 1877
- 165\*Dick, George Handasyde, 136 Buchanan street. 1887
- \*Dixon, A. Dow, 10 Montgomerie crescent, Kelvinside. 1873
- Dobbie, A. B., M.A., University. 1885
- Donald, John, Townhead Public School. 1872
- Donald, William J. A., 70 Great Clyde street. 1877

- 170 Donaldson, James, Gas-works, Cambuslang. 1890  
 Dougall, Franc Gibb, 167 Canning street. 1875  
 Dougall, John, M.D., C.M., F.F.P.S.G., Professor of Materia Medica, St. Mungo's College, 6 Belmar terrace, Pollokshields. 1876  
 Douglas, Campbell, I.A., F.R.I.B.A., 266 St. Vincent street. 1870  
 Downie, Robert, jun., Carntyne Dye-works, Parkhead. 1872  
 175 Downie, Thomas, Hyde Park Foundry. 1886  
 Drew, Alex., 12 St. Vincent place. 1869  
 Duncan, Eben., M.D., C.M., F.F.P.S.G., 4 Royal crescent, Crosshill. 1873  
 \*Duncan, Robert, Whitefield Works, Govan. 1890  
 \*Duncan, Walter, 9 Montgomerie crescent. 1881  
 180\* Dunlop, Nathaniel, 25 Bothwell street. 1870  
 Dunn, Robert Hunter, 4 Belmont crescent. 1878  
 Dyer, Henry, M.A., D.Sc., C.E., 8 Highburgh terrace, Dowanhill. 1883  
 Eadie, Alexander, 280 Cathcart road. 1885  
 Easton, Walter, 125 Buchanan st. 1878  
 185 Easton, William J., 150 West Regent street. 1876  
 \*Edwards, John, Govanhaugh Dye-works. 1883  
 Edwards, Matthew, 209 Sauchiehall street. 1887  
 Elgar, Francis, LL.D., Fairfield Works, Govan. 1884  
 \*Ellis, T. Leonard, North British Iron-works, Coatbridge. 1888  
 190 Erskine, Jas., M.A., M.B., L.F.P.S., 5 Charing Cross mansions. 1886  
 \*Ewing, Wm., 7 Royal Bank place. 1883  
 Fairweather, Wallace, C.E., 62 St. Vincent street. 1880  
 Falconer, Patrick, 33 Hayburn crescent, Partick. 1876  
 Falconer, Thos., 50 Kelvingrove st. 1880  
 195 Farquhar, John, 13 Belhaven terrace. 1872  
 Farquhar, Wm. R., 13 Belhaven terrace. 1892  
 Faulds, W. B., Westfield, Ibrox. 1890  
 Fawsitt, Charles A., 9 Foremount terrace, Partick. 1879  
 Fergus, Freeland, M.D., F.F.P.S.G., 3 Elmbank crescent. 1887  
 200 Ferguson, D. Scott, 10 Belhaven terrace. 1890  
 \*Ferguson, John, M.A., LL.D., F.R.S.E., Professor of Chemistry, University of Glasgow. 1869  
 Ferguson, Peter, 15 Bute gardens, Hillhead. 1866  
 Ferguson, Thomas, 124 Salamanca street, Parkhead. 1883  
 Fergusson, Alex. A., 48 M'Alpine street. 1847  
 205 Fife, William, 52 Glassford street. 1880  
 Finlay, H. G., 16 Westbourne terrace. 1888  
 Findlay, Joseph, Clairmont, Winton drive, Kelvinside. 1873  
 Finlayson, James, M.D., 2 Woodside place. 1873  
 \*Fleming, James, 136 Glebe street. 1880  
 210\* Fleming, William James, M.D., 3 Woodside terrace. 1876  
 Fotheringham, T. B., 65 West Regent street. 1889  
 Foulis, William, C.E., 45 John st. 1870  
 \*Fowler, John, 5 Derby street, Sandyford. 1880  
 Frame, James, Union Bank of Scotland, 113 King street, Tradeston. 1885  
 215 Fraser, Matthew P., 91 W. Regent street. 1887  
 Fraser, Melville, 31 St. Vincent pl. 1890  
 Frazer, Daniel, 127 Buchanan st. 1853  
 Frew, Alex., C.E., 175 Hope street. 1876  
 Fullarton, J. H., M.A., B.Sc., Fishery Board Office, Edinburgh. 1886  
 220 Fulton, David, Roxburgh villa, Bothwell. 1891  
 Fulton, R. C., 2 Lugar place, Kelvinside. 1890  
 Fyfe, Peter, 1 Montrose street. 1886  
 Gairdner, Charles, LL.D., Broom, Newton-Mearns. 1884  
 \*Gairdner, C. D., C.A., 115 St. Vincent street. 1886  
 225 Gairdner, W. T., M.D., LL.D., Professor of Practice of Medicine in the University of Glasgow, 225 St. Vincent street. 1863  
 Galbraith, Peter, 17 Huntly gardens. 1886  
 Gale, James M., C.E., 45 John street. 1851  
 Galloway, T. Lindsay, C.E., 43 Mair street, Plantation. 1883  
 Gardner, Daniel, 36 Jamaica street. 1861  
 230\* Garrow, James R., 32 Elmbank crescent. 1890  
 \*Garroway, John, 694 Duke st. 187  
 Geddes, Wm., 8 Battlefield crescent, Langside. 184  
 Gillies, W. D., 17 Royal Exchange square. 187

- Gilfillan, Wm., 129 St. Vincent st. 1881  
 235 Glaister, John, M.D., F.F.P.S.G.,  
 D.P.H., Camb., &c., Professor of  
 Medical Jurisprudence and Public  
 Health, St. Mungo's College, 4  
 Grafton place. 1879  
 Goldie, James, 40 St. Enoch square. 1883  
 Goodwin, Robert, 58 Renfield  
 street. 1875  
 Gorman, C. S., 6 Broomhill avenue,  
 Partick. 1890  
 Gourlay, John, C.A., 24 George sq. 1874  
 240 Gourlay, Robert, 4 Granby terrace,  
 Hillhead. 1869  
 Gow, Leonard, 19 Waterloo street. 1889  
 Gow, Leonard, jun., 19 Waterloo  
 street. 1884  
 Gow, Robert, Cairndowan, Dowan-  
 hill gardens. 1860  
 Graham, Alex. M., Rowanlea, 7 St.  
 Andrew's drive, Pollokshields. 1887  
 245 Graham, Robert, 108 Eglinton st. 1888  
 \*Graham, William, 11 Claremont ter. 1885  
 Grant, Robt., M.A., LL.D., F.R.S.,  
 Professor of Astronomy in the Uni-  
 versity of Glasgow, Observatory,  
 Hon. Vice-President. 1860  
 Gray, Andrew, 30 Bath street. 1889  
 Gray, James, M.D., 15 Newton  
 terrace. 1863  
 250 Gray, James, 2 Balmoral crescent,  
 Crosshill. 1876  
 Greenlees, Alex., M.D., 33 Elm-  
 bank street. 1864  
 Grierson, James, 5 Belhaven cres.,  
 Kelvinside. 1880  
 Grieve, John, M.A., M.D., F.R.S.E.,  
 care of W. L. Buchanan, 212 St.  
 Vincent st. 1856  
 Griffiths, Azariah, Elmbank, Fal-  
 kirk. 1886  
 255 Guthrie, John, 50 M'Culloch st. 1891  
 Halket, George, M.D., F.F.P.S.G.,  
 4 Royal cres., W. 1889  
 Hamilton, John, I.A., 212 St. Vin-  
 cent street. 1885  
 Hannay, Jas. B., F.R.S.E., F.C.S.,  
 New Club, West George street. 1879  
 Harley, George, 29 Burnbank gar. 1891  
 260 Hart, Arthur, 20 Woodlands ter. 1883  
 \*Harvie, John, Secretary, Clydesdale  
 Bank, 30 St. Vincent place. 1880  
 Harvie, William, 8 Bothwell ter-  
 race, Hillhead. 1888  
 \*Henderson, A. P., 10 Crown terrace,  
 Dowanhill. 1880  
 Henderson, George G., D.Sc., M.A.,  
 F.I.C., F.C.S., Professor of Chem-  
 istry, Glasgow and West of Scot-  
 land Technical College, 204 George  
 street. 1883  
 265\*Henderson, John, jun., Meadows-  
 Works, Partick. 1879  
 Henderson, John, Towerville,  
 Helensburgh. 1890  
 Henderson, Robert, 330 Renfrew  
 street. 1885  
 Henderson, Thomas, 47 Union  
 street. 1855  
 Henderson, Wm., Ennerdale, Win-  
 ton drive, Kelvinside. 1853  
 270\*Henderson, Wm., 4 Windsor ter-  
 race, West. 1873  
 Henry, R. W., 8 Belhaven crescent,  
 Kelvinside. 1875  
 Heys, Zechariah J., South Arthurlie,  
 Barrhead. 1870  
 Higginbotham, James S., 4 Spring-  
 field court, 69 Queen street. 1874  
 Higginbotham, Robert Ker, 4 Spring-  
 field court, 69 Queen street. 1885  
 275 Higgins, Henry, jun., 247 St. Vin-  
 cent street. 1878  
 Hodge, William, 27 Montgomery  
 drive, Kelvinside. 1878  
 Hogg, Robert, 9 Nithsdale drive,  
 Pollokshields. 1865  
 Honeyman, John, F.R.I.B.A., 140  
 Bath street. 1870  
 Horne, R. R., C.E., 150 Hope st. 1876  
 280 Horton, William, Birchfield, Mount  
 Florida. 1889  
 Howat, William, 37 Elliot street. 1885  
 Howatt, James, I.M., 146 Buchanan  
 street. 1870  
 Howatt, William, I. M., 146  
 Buchanan street. 1870  
 Hunt, Edmund, 87 St. Vincent st. 1856  
 285\*Hunt, John, Milton of Campsie. 1881  
 \*Hunter, Wm. S., 30 Hope street. 1889  
 Hutchison, Peter, 3 Lilybank terrace,  
 Hillhead. 1889  
 Inglis, R. A., Arden, Bothwell. 1889  
 \*Jack, William, M.A., LL.D., Pro-  
 fessor of Mathematics in the Uni-  
 versity of Glasgow. 1881  
 290 Jackson, William V., 25 Stanley  
 street, W. 1888  
 Jamieson, Andrew, F.R.S.E.,  
 M.Inst.C.E., M.Inst.E.E., &c.,  
 Professor of Engineering, 38 Bath  
 street. 1881  
 Johnston, David, 160 West George  
 street. 1891  
 Johnstone, Jas., Coatbridge street,  
 Port-Dundas. 1869  
 Jolly, William, F.G.S., F.R.S.E.,  
 Greenhead house, Govan. 1890  
 295 Kay, Wm. E., F.C.S., Gowanbank,  
 Clarkston, Busby. 1887

- Kean, James, 32 Scotia street, Garnethill. 1888
- Kelly, James K., M.D., F.F.P.S.G., Park villa, Queen Mary avenue, Crosshill. 1889
- Kelvin, The Right Hon. Lord, LL.D., D.C.L., P.R.S., F.R.S.E., Professor of Natural Philosophy, University of Glasgow, *Hon Vice-President.* 1846
- Kennedy, Hugh, Redclyffe, Partick. 1876
- 300 Kennedy, James, 33 Greendyke st. 1889
- Ker, Charles, M.A., C.A., 115 St. Vincent street. 1885
- \*Ker, Wm., 1 Windsor ter., west. 1874
- Kerr, Adam, 175 Trongate. 1887
- Kerr, Charles James, 40 West Nile street. 1877
- 305 Kerr, Geo. Munro, 97 Buchanan street. 1890
- Kerr, James Hy., 13 Virginia st. 1872
- Kerr, John G., M.A., 15 India st. 1878
- Key, William, Tradeston Gas-works. 1877
- King, James, 57 Hamilton drive, Hillhead. 1848
- 310 King, Sir James, Bart., LL.D., of Campsie, 115 Wellington street. 1855
- Kirk, Robert, M.D., Newton cottage, Partick. 1877
- Kirkpatrick, Alexander B., 88 St. Vincent street. 1885
- Kirkpatrick, Andrew J., 179 West George street. 1869
- Kirkwood, James, Carling lodge, Ibrox. 1890
- 315 Knox, Adam, 47 Crownpoint road. 1881
- \*Knox, David J., 19 Renfield street. 1890
- Knox, John, 58 Bath street. 1883
- Laird, George H., 159 Greenhead street. 1882
- Laird, John, Marchmont, Port-Glasgow. 1876
- 320 Laird, John, Royal Exchange Sale Rooms. 1879
- Lamb, Thomas, 220 Parliamentary road. 1870
- Lang, William, jun., F.C.S., Crosspark, Partick. 1865
- Latta, James, 73 Mitchell street. 1869
- Latta, John, 138 West George street. 1880
- 325 Leggat, William, Buchanan Institution. 1889
- Leitch, Alexander, 60 Rosebank terrace, Grant street. 1886
- Lester, William, 2 Doune terrace, N. Woodside. 1884
- \*Lindsay, Archd. M., M.A., 87 West Regent street. 1872
- \*Long, John Jex, 11 Doune terrace, Kelvinside. 1862
- 330 Love, James Kerr, M.D., C.M., 4 Matilda place, Strathbungo. 1888
- Lundholm, C. O., Nobel's Explosives Factory, Ardeer, Stevenston. 1890
- M'Ara, Alex., 65 Morrison street. 1888
- Macarthur, J. G., Rosemary villa, Bowling. 1874
- \*Macarthur, John S., 13 West Scotland street. 1890
- 335 M'Call, Samuel, 16 Hillsborough square, Hillhead. 1882
- M'Callum, Robert, jun., 69 Union street. 1891
- \*M'Clelland, Andrew Simpson, C.A., 4 Crown gardens, Dowanhill. 1884
- M'Conville, John, M.D., 27 Newton place. 1870
- M'Cracken, James, 5 Bowmont terrace, Kelvinside. 1889
- 340 M'Crae, John, 7 Kirklee gardens, Maryhill. 1876
- M'Creath, James, M.E., 208 St. Vincent street. 1874
- M'Culloch, Hugh, 154 West Regent street. 1880
- Macdonald, Archibald G., 8 Park circus. 1869
- Macdonald, Thomas, 205 St. Vincent street. 1869
- 345 Macdonald, Thomas F., M.B., C.M., Burgh house, Maryhill. 1889
- Macfarlane, Walter, Crosslea house, Thornliebank. 1869
- \*Macfarlane, Walter, 12 Lynedoch crescent. 1885
- M'Farlane, Wm., Edina lodge, Rutherglen. 1888
- \*M'Gilvray, R. A., 129 West Regent street. 1880
- 350 M'Gregor, Duncan, F.R.G.S., 37 Clyde place. 1867
- M'Gregor, James, 1 East India avenue, London, E.C. 1872
- M'Houl, David, Ph.D., Dalquhurn Works, Renton. 1883
- M'Intyre, Wm., Marion bank, Rutherglen. 1888
- Mackay, John Yule, M.D., 34 Elmbank crescent. 1885
- 355 \*M'Kenzie, W. D., 43 Howard st. 1875
- \*M'Kenzie, W. J., 1 Oakfield ter., Hillhead. 1879
- \*M'Kendrick, John G., M.D., C.M., LL.D., F.R.S., F.R.S.E., F.R.C.P.E., Professor of Institutes of Medicine in the University of Glasgow, 45 Westbourne gardens, *President.* 1877
- Mackinlay, David, 6 Great Western terrace, Hillhead. 1855

- \*Mackinlay, James Murray, 4 Westbourne gardens. 1886
- 360 Mackinlay, Wm., 2 Belmont crescent., Hillhead. 1887
- M'Kissack, John, 68 West Regent street. 1881
- MacLae, A. Crum, 147 St. Vincent street. 1884
- MacLean, Walter, 2 Bothwell cir. 1887
- \*MacLay, David T., 169 W. George st. 1879
- 365 Maclean, A. H., 8 Hughenden terrace, Kelvinside. 1870
- Maclean, Magnus, M.A., F.R.S.E., 8 St. Albans terrace, Hillhead. 1885
- MacLehose, James J., M.A., 61 St. Vincent street. 1882
- M'Lennan, James, 40 St. Andrew's street. 1888
- Macouat, R. B., 37 Elliot street 1885
- 370 Macphail, Donald, M.D., Garturk cottage, Whifflet, Coatbridge. 1877
- M'Phee, Donald, The Oaks, Fort William. 1889
- M'Pherson, George L., 26 Albert road, Crosshill, East. 1872
- M'Vail, D. C., M.B., 3 St. James' terrace, Hillhead. 1873
- M'Whirter, William, Faraday Electrical Works, Govan. 1889
- 375 Machell, Thomas, 39 Great Western road. 1886
- Main, Robert B., Broompark, Ardrossan. 1885
- Mann, John, C.A., 188 St. Vincent street, *Treasurer*. 1856
- Mann, John, jun., M.A., C.A., 188 St. Vincent street. 1885
- Manwell, James, The Hut, 4 Albert drive, Pollokshields. 1876
- 380 Martin, W. C., 137 West Regent street. 1889
- Marwick, Sir J. D., LL.D., F.R.S.E., 19 Woodside terrace. 1878
- Mathieson, Thomas A., 3 Grosvenor terrace. 1869
- Mavor, Alfred E., Victoria mansions, 32 Victoria street, London, W. 1890
- Mavor, Henry A., 56 George sq. 1887
- 385 Mavor, James, 63 Bank street, Hillhead. 1885
- Mavor, Samuel, 4 Elmbank cres. 1890
- Mayer, John, Strathview, Cathkin road, Langside, *Secretary*. 1860
- Mechan, Arthur, 60 Elliot street. 1876
- Mechan, Henry, 60 Elliot street. 1879
- 390 Meikle, Andrew W., M.A., Viewfield house, Pollokshields. 1890
- Menzies, Thos., Hutchesons' Grammar School, Crown street. 1859
- \*Menzies, Thos. J., M.A., B.Sc., F.C.S., Stranraer Academy, Stranraer. 1887
- Millar, James, 158 Parliamentary road. 1870
- Miller, A. Buchanan, 13 North Claremont street. 1891
- 395 Miller, A. Lindsay, 124 Bath street. 1878
- \*Miller, Arch. Russell, 28 Lilybank gardens, Hillhead. 1884
- Miller, David S., 8 Royal crescent, W. 1887
- \*Miller, George, Winton drive, Kelvinside. 1881
- Miller, G. J., Frankfield, Shettleston. 1888
- 400 Miller, John (Messrs. James Black & Co.), 23 Royal Exchange square. 1874
- Miller, Richard, 54 St. Enoch square. 1885
- \*Miller, Thos. P., Cambuslang Dye-works. 1864
- Miller, W. M., 7 Mansfield place, West Regent street. 1867
- Mills, Edmund J., D.Sc., F.R.S., "Young" Professor of Technical Chemistry, 60 John street. 1875
- 405 Milne, William, M.A., B.Sc., F.R.S.E., High School. 1881
- Mirrlees, James B., Redlands, Kelvinside. 1869
- \*Mirrlees, William J., 42 Aytoun road, Pollokshields. 1889
- \*Mitchell, George A., 67 West Nile street. 1883
- Mitchell, Jas. L., 10 Gt. Western terrace. 1878
- 410 Mitchell, Robert, 12 Wilson street, Hillhead. 1870
- \*Moffatt, Alexander, 23 Abercromby place, Edinburgh. 1874
- Moir, Charles S., 92 Union street. 1884
- Mollison, James, 6 Hillside gardens, Partick. 1889
- \*Mond, Robert Ludwig, B.A. (Cantab), F.R.S.E., 20 Avenue road, Regent's park, London, N.W. 1890
- 415\*Monteith, Robert, Greenbank, Dowanhill gardens. 1885
- Moore, Alexander, C.A., 209 West George street. 1869
- Moore, Alexander George, M.A., B.Sc., 13 Clairmont gardens. 1886
- Morgan, John, Springfield house, Bishopbriggs. 1844
- Morrice, Jas. A., 1 Athole gardens place. 1883
- 420 Motion, James Russell, 38 Cochran street. 1887
- Muir, Alex., 400 Eglinton street. 1883
- \*Muir, Allan, 36 George street. 1881
- Muir, James, C.A., 149 West George street. 1887

- Muir, Sir John, Bart., 6 Park gar. 1876  
 425\* Muirhead, Andrew Erskine, Cart Forge, Crossmyloof. 1873  
 Muirhead, James, 10 Doune gardens, Kelvinside. 1887  
 \*Muirhead, Robert F., M.A., B.Sc., Mason College, Birmingham. 1879  
 Munro, Daniel, 10 Doune terrace, Kelvinside. 1867  
 Munsie, George, 1 St. John's ter., Hillhead. 1871  
 430 Munsie, Robert George, 10 Berkeley terrace, West. 1883  
 \*Murdoch, Robert, 19 Commerce st. 1880  
 Murdoch, Thomas, 115 Bothwell street. 1892  
 Murdoch, William, 11 Bothwell st. 1879  
 \*Murray, David, LL.D., 169 West George street. 1876  
 435 Murray, John Bruce, 65 Great Clyde street. 1890  
 Murray, A. Erskine, Sheriff-Substitute of Lanarkshire, Sundown, Montgomerie drive. 1881  
 Napier, Alex., M.D., F.F.P.S.G., Rose Bank, Queen Mary avenue, Crosshill. 1886  
 Napier, James, 15 Prince's square, Strathbungo. 1870  
 Napier, James A., 55 Cathedral st. 1890  
 440\* Napier, John, 23 Portman square, London. 1846  
 Nelson, Alex., 80 Gordon street. 1880  
 Nelson, D. M., 68 Bath street. 1875  
 \*Newlands, Joseph F., 28 Renfield street. 1883  
 Nisbet, Robert, Star Foundry, Kinning Park. 1890  
 445 Ogilvie, William, 1 Doune terrace. 1881  
 Orr, Robert, 79 West Nile street. 1890  
 Osborne, Alex., 5 Oakley terrace, Dennistoun. 1870  
 Osborne, Robert, 3 Montgomerie crescent. 1890  
 Outram, D. E., 16 Grosvenor ter., Hillhead. 1878  
 450 Park, James, 51 Millburn street. 1877  
 \*Parker, John Dunlop, C.E., 146 West Regent street. 1889  
 \*Parnie, James, 32 Lynedoch street. 1874  
 \*Paterson, Robert, C.A., 28 Renfield street. 1881  
 Paton, James, F.L.S., Corporation Galleries, and Kelvingrove Museum. 1876  
 455 Patterson, T. L., F.C.S., at John Walker & Co.'s, Greenock. 1873  
 Petrie, Alexander, I.A., 109 Bath street. 1885  
 Pirie, John, M.D., 26 Elmbank crescent. 1877  
 \*Pirrie, Robert, 9 Buckingham ter. 1875  
 \*Pollock, R., M.B., C.M., F.F.P. & S.G., Laurieston house, Pollokshields. 1883  
 460 Price, Rees, L.D.S., Eng., 163 Bath street. 1883  
 Pride, David, M.D., Townhead House, Neilston. 1887  
 Prince, Edward E., B.A. (Cantab), F.L.S., Professor of Zoology, St. Mungo's College. 1892  
 \*Provan, James, 40 West Nile st. 1868  
 Provand, A. D., M.P., 8 Bridge street, London, S.W. 1888  
 465 Raalte, Jacques Van, 104 West George street. 1884  
 Ramsay, Robert, M.D., L.R.C.S.E., Lochwinnoch. 1881  
 Ramsey, Robert, 14 Park terrace. 1889  
 Rankine, David, C.E., 5 West Regent street. 1875  
 Rattray, Rev. Alex., M.A., Parkhead parish, 4 Westercraigs, Dennistoun. 1879  
 470 Rattray, William A., 233 Hope st. 1890  
 Reid, Andrew, Houston place, S.S. 1875  
 Reid, David, 16 Cambridge street. 1887  
 \*Reid, Hugh, Belmont, Springburn. 1880  
 Reid, James, 10 Woodside terrace. 1870  
 475 Reid, James, 15 Montgomerie cres. 1889  
 Reid, Thos., M.D., 11 Elmbank st. 1869  
 Reid, William, M.A., 51 Grant st. 1881  
 \*Reid, William L., M.D., 7 Royal crescent, West. 1882  
 Reith, Rev. George, M.A., D.D., Free College Church, 37 Lynedoch st. 1876  
 480 Renton, James Crawford, M.D., L.R.C.P. & S.Ed., 1 Woodside terrace. 1875  
 Rey, Hector, B.L., B.Sc., 2 Viningcombe street, Hillhead. 1889  
 Richmond, Thos., L.R.C.P.E., 559 New City road. 1887  
 Ritchie, George, Parkhead Forge and Steel Works. 1890  
 Robertson, Rev. James, D.D., Professor of Oriental Languages in the University of Glasgow. 1884  
 485 Robertson, John, 10 Valeview ter., Langside, Librarian. 1860  
 Robertson, J. M'Gregor, M.A., M.B., C.M., 26 Buckingham ter., Hillhead. 1881  
 Robertson, Robert, Coplawhill, Pollokshaws road. 1877  
 Robertson, Robert A., 8 Park street, East. 1877  
 Robertson, Robert H., Clyde bank, Rutherglen. 1888

- 490 Robertson, William, C.E., 123 St. Vincent street. 1869  
 \*Rogers, John C., 224 St. Vincent st. 1888  
 Rose, Alexander, Richmond house, Dowanhill. 1879  
 \*Rose, Charles A., 1 Belhaven cres. 1889  
 Ross, David, M.A., B.Sc., LL.D., E.C. Training College. 1888  
 495 Ross, Henry, 7 Park quadrant. 1876  
 \*Ross, John, 9 Westbourne gardens. 1885  
 Rottenburg, Paul, 21 St. Vincent place. 1872  
 Rowan, David, 22 Woodside place. 1863  
 Rowan, W. G., 234 West George street. 1881  
 500 Rundell, R. Cooper, Underwriters' Room, Royal Exchange. 1877  
 Russell, James B., B.A., M.D., LL.D., 3 Foremount terrace, Partick, *Hon. Vice-President*. 1862  
 Salmon, W. Forrest, F.R.I.B.A., 197 St. Vincent street. 1870  
 Sayers, William Brooks, 56 George square. 1890  
 Schmidt, Alfred, 492 New City road. 1881  
 505 Scott, Alex., 2 Lawrence place, Dowanhill. 1871  
 \*Scott, D. M'Laren, 2 Park quadrant. 1881  
 Scott, John, 140 Douglas street. 1891  
 Scott, Robt., I.M., 115 Wellington street. 1884  
 Seligmann, Hermann L., 135 Buchanan street. 1850  
 510 Sexton, A. Humboldt, F.C.S., F.I.C., F.R.S.E., Professor of Metallurgy, Glasgow and West of Scotland Technical College, 204 George street. 1892  
 Shields, Thomas, M.A., 12 Queen's crescent, Cathcart. 1890  
 Simons, Michael, 206 Bath street. 1880  
 Simpson, P. A., M.A. (Cantab.), M.D., Regius Professor of Forensic Medicine, University, 216 West George street. 1881  
 Sinclair, Alexander, Ajmere lodge, Langside. 1883  
 515 Smart, William, M.A., Nunholm, Dowanhill. 1886  
 Smellie, George, I.M., 167 St. Vincent street. 1880  
 \*Smellie, Thos. D., 209 St. Vincent street. 1871  
 Smith, D. Johnstone, C.A., 149 W. George street. 1888  
 Smith, Francis, Ashfield, Bothwell. 1875  
 520 Smith, Harry J., Ph.D., Coltness Iron-works, Newmains. 1877  
 Smith, Hugh C., 55 Bath street. 1861  
 \*Smith, J. Guthrie, 54 West Nile st. 1875  
 \*Smith, Robert B., Bonnybridge, Stirlingshire. 1884  
 Smith, W. R. W., Rosmor, Sandbank. 1868  
 525 Smith, William, jun., 1 University Gardens terrace, Hillhead. 1890  
 Snodgrass, James, F.C.S., 2 Keir terrace, Pollokshields. 1878  
 Snodgrass, William, M.A., M.B., C.M., Muirhead Demonstrator of Physiology, University of Glasgow, 11 Victoria crescent, Dowanhill. 1890  
 \*Somerville, Alexander, B.Sc., F.L.S., 4 Bute Mansions, Hillhead street, Hillhead. 1888  
 Somerville, Graham, 58 W. Regent street. 1892  
 530 Sorley, Robert, 3 Buchanan st. 1878  
 Spencer, Charles L., Edgehill, Kelvinside. 1891  
 Spens, John A., 169 W. George st. 1879  
 \*Spiers, John, 43 Great Western road, Hillhead. 1885  
 Stanford, Edward C. C., F.C.S., Glenwood, Dalmuir, Dumbartonshire. 1864  
 535 \*Steel, William Strang, Philiphaugh, Selkirk. 1889  
 \*Stephen, John, Domira, Partick. 1880  
 Stephen, Robt. R., Adelphi Biscuit Factory. 1867  
 \*Steven, Hugh, Westmount, Montgomerie drive. 1869  
 Steven, John, 32 Elliot street. 1875  
 540 \*Stevenson, D. M., 12 Waterloo st. 1889  
 \*Stevenson, Jas., F.R.G.S., 23 West Nile street. 1870  
 Stevenson, John, C.E., 208 St. Vincent street. 1885  
 Stevenson, John, 12 Victoria road, Lenzie. 1892  
 Stevenson, William, Tower bank, Lenzie. 1870  
 545 Stevenson, Wm., 21 Clyde place. 1888  
 Stewart, Andrew, 41 Oswald street. 1887  
 Stewart, David, 3 Clifton place. 1856  
 Stewart, James, 2 Lawrence place, Dowanhill. 1891  
 Stewart, James Reid, 30 Oswald street. 1845  
 550 Stewart, John, Western Saw Mills. 1877  
 Stobo, Thomas, Somerset house, Garelochhead. 1884  
 Stoddart, James Edward, Howden, Mid-Calder, N.B. 1872  
 \*Strain, John, C.E., 154 West George street. 1876  
 Summers, John, 174 West Nile st. 1891  
 555 \*Sutherland, David, Great Western Hotel, Oban. 1880

- \*Sutherland, John, Great Western Hotel, Oban. 1880  
 Sutherland, J. R., 6 Clifton place. 1884  
 Sutherland, Malcolm, Leven Shipyard, Dumbarton. 1890  
 Sutherland, Robert, 28 Woodside place. 1875  
 560 Swan, Charles C., 15 Rose street, Garnethill. 1891  
 Tatlock, John, F.I.C., 34 Gray street, Sandyford. 1875  
 Tatlock, Robt. R., F.R.S.E., F.I.C., F.C.S., 156 Bath street. 1868  
 Taylor, Benjamin, F.R.G.S., 10 Derby crescent, Kelvinside. 1872  
 Taylor, Thomas, 60 Montrose street. 1889  
 565 Teacher, Adam, 14 St. Enoch sq. 1868  
 Tennant, Sir Charles, Bart., 195 West George street. 1868  
 Tennent, Gavin P., M.D., 159 Bath street. 1875  
 Thomas, Moses, M.D., Superintendent, Royal Infirmary. 1890  
 Thomson, David, I.A., F.R.I.B.A., 2 West Regent street. 1869  
 570 Thomson, George C., F.C.S., 23 Kersland terrace, Hillhead. 1883  
 Thomson, Gilbert, M.A., C.E., 75 Bath street. 1885  
 Thomson, Graham Hardie, 2 Marlborough terrace, Kelvinside. 1869  
 \*Thomson, James, F.R.I.B.A., 88 Bath street. 1886  
 Thomson, James, F.G.S., 26 Leven street, Pollokshields. 1863  
 575 Thomson, Jonathan, 3 St. John's terrace, Hillhead. 1869  
 Thorne, George, jun., 1 Annfield terrace, West, Partick. 1891  
 Townsend, C. W., Crawford street, Port-Dundas. 1890  
 \*Tullis, James Thomson, Anchorage, Burnside, Rutherglen. 1883  
 \*Turnbull, John, jun., M.I.M.E., 18 Blythswood square. 1883  
 580 Turner, George A., M.D., 1 Clifton place, Sauchiehall street. 1883  
 Turner, William, Rachan house, Helensburgh, N.B. 1875  
 Verel, Wm. A., The Linn, Cathcart. 1883  
 Walker, Adam, 35 Elmbank cres. 1880  
 \*Walker, Archibald, B.A. (Oxon.), F.C.S., 8 Crown ter., Dowanhill. 1885  
 585 Walker, Malcolm M'N., F.R.A.S., 7 Westbourne ter., Fort Matilda, Greenock. 1853  
 \*Wallace, Hugh, 30 Havelock street. 1879  
 \*Wallace, Wm., M.A., M.B., C.M., Westfield house, Shawlands. 1888  
 Wallace, William, M.A., Allan Glen's School. 1890  
 Warren, John A., C.E., 115 Wellington street. 1887  
 590 Watson, Archibald, 5 Westbourne terrace. 1881  
 Watson, James, 24 Sandyford place. 1873  
 \*Watson, John, 205 West George street. 1886  
 Watson, Joseph, 225 West George street. 1882  
 Watson, J. Robertson, M.A., Professor of Chemistry, Anderson's College Medical School. 1891  
 595 \*Watson, Thomas Lennox, I.A., F.R.I.B.A., 108 W. Regent st. 1876  
 \*Watson, Sir William Renny, 16 Woodlands terrace. 1870  
 Welsh, Thomas M., 3 Prince's gardens, Dowanhill. 1883  
 Wenley, James A., Bank of Scotland, Edinburgh. 1870  
 Westlands, Robert, 99 Mitchell street. 1869  
 600 White, John, Scotstoun Mills, Partick. 1875  
 \*Whitson, Jas., M.D., F.F.P. & S.G., 13 Somerset place. 1882  
 Whytlaw, R. A., 1 Windsor quadrant, Kelvinside. 1885  
 Widmer, Justus, 21 Athole gardens. 1887  
 Williamson, John, 65 West Regent street. 1881  
 605 Wilson, Alex., Hydepark Foundry, 54 Finnieston street. 1874  
 Wilson, David, Carbeth, by Killearn. 1850  
 Wilson, Richard J., St. George's Road Public School. 1887  
 Wilson, William, Virginia buildings. 1881  
 Wilson, William, Stocklach, Malpas, Cheshire. 1889  
 610 Wilson, W. H., 21 Hope street. 1881  
 Wingate, Arthur, 6 Kelvin drive. 1882  
 \*Wingate, John B., 7 Crown terrace, Dowanhill. 1881  
 Wingate, P., 14 Westbourne ter. 1872  
 Wingate, Walter E., 4 Bowmont terrace. 1880  
 615 Wood, James, M.A., Glasgow Academy. 1885  
 Wood, James, 28 Royal Exchange square. 1886  
 Wood, Wm. Copland, Turkey-red Works, Alexandria. 1883  
 Wood, W. E. H., 40 Candleriggs. 1891  
 Woodburn, J. Cowan, M.D., 197 Bath street. 1869  
 620 Wyper, James, 7 Bowmont gardens. 1878

*List of Members.*

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Yellowlees, D., M.D., LL.D., Physician-Superintendent, Gart- navel. 1881	625 Young, Thomas, Pollok Patents Gold Extracting Company, 27 St. Vincent place. 1892
Young, John, 2 Montague terrace, Kelvinside. 1885	*Young, Thos. Graham, Westfield, West Calder. 1880
Young, John, 64 Cochrane street. 1881	Younger, George, 166 Ingram street. 1847
*Young, John, jun., M.A., B.Sc., 38 Bath street. 1887	Zinkeisen, Victor, 225 George st. 1881

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